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Монтаж и регулировка радиоаппаратуры

ИЗДАТЕЛЬСТВО «ВЫСШАЯ ШКОЛА»
МОСКВА

A. BELEVTSEV

RADIO CIRCUIT CONSTRUCTION

Translated from the Russian
by
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TRANSLITERATION OF THE RUSSIAN ALPHABET

Russian	Transliteration	Russian	Transliteration
А а	a	Р р	r
Б б	b	С с	s
В в	v	Т т	t
Г г	g	У у	u
Д д	d	Ф ф	f
Е е	e	Х х	kh
Ж ж	zh	Ц ц	ts
З з	z	Ч ч	ch
И и	i	Ш ш	sh
К к	k	Щ щ	shch
Л л	l	Ы ы	y
М м	m	Э э	é
Н н	n	Ю ю	yu
О о	o	Я я	ya
П п	p		

На английском языке

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FOREWORD

The manufacture of radio-electronic equipment comprises component fabrication, assembly, wiring and alignment of the equipment. The process involves a vast variety of operations and specialized equipment and instrumentation.

A modern radio or electronic system incorporates several thousand components; it involves a great variety of operations, alignment being the most time-consuming.

This book gives the basic characteristics and features of radio equipment; general requirements for operation, storage, transportation, assembly and alignment. The service life and trouble-free operation of radio equipment to a great extent depend on the quality of assembly and alignment.

Due emphasis has been placed on assembly and wiring of radio equipment. In addition to general information on assembly operations, specific data required for practical work are also given. Much space is allotted to the packaging of radio equipment. The entire field of assembly is explained and essential safety rules are stated. Much attention is given to the problems of mechanization and automation of individual assembly operations, such as wire cutting and stripping, soldering and welding of radio components, etc. Examples are given of wiring practice for specific types of equipment.

Attempts to mechanize and particularly to automate the packaging of radio equipment on an extensive scale have failed and during the last 10-15 years new efforts have been made to develop new assembly methods to mechanize labour-consuming operations. New methods of manufacture called for new principles of radio equipment design which

resulted in the development of printed circuit techniques which are also discussed.

Since all the stages of radio equipment assembly must be closely checked the book explains the principal methods of electrical measurements. Attention is paid to the discussion of fundamental problems and specific methods of radio equipment alignment.

CHAPTER ONE

CIRCUIT COMPONENTS

1. Capacitors

CLASSIFICATION AND PURPOSE

According to design and application capacitors employed in radio work may be classified into *fixed, trimmer,* and *variable.*

Fixed capacitors are used as elements of tuned circuits, as temperature compensating, coupling or blocking devices.

Trimmer capacitors are semiadjustable devices. These capacitors are used in tuning to compensate the spread of parameters in circuit elements. They are extensively used in fine continuous tuning to compensate the spread in the circuit initial capacitance, to adjust capacitive coupling to the required value, and to tune circuits to the required (fixed) frequencies, and for other applications.

Variable capacitors are mainly used for tuning resonant circuits within a definite range.

The basic parameters of capacitors are the nominal capacitance, class of precision, working voltage and power-loss (leakage) factor. The rated capacitance is determined by the size of capacitor plates, spacing between them, and the dielectric constant. Fixed capacitors are most commonly used. Depending on the insulating material used they may be defined as paper, mica, ceramic, electrolytic, etc.

The class of precision of a capacitor indicates the percentage deviation from the nominal or rated capacitance.

According to permissible percentage deviation multipurpose capacitors are grouped into three classes of precision with respective values of ±5, ±10 and ±20 per cent. Choice of the precision class depends upon the circuit requirements. Thus, the Ist class capacitors are employed, for example, in tuned circuits and in circuit stages with high-precision operational requirements. In circuits that can tolerate relatively wide changes in capacitance (e.g. decoupling and blocking circuits) class III capacitors are quite applicable.

The rated d.c. voltage is indicated on most types of capacitors. The a.c. (effective) voltage for the capacitor should be 1.5 to 2 times less than d.c. voltage. For capacitors employed in pulse circuits the sum of the d.c. voltage and the amplitude value of the a.c. voltage must not exceed the rated voltage. Multipurpose capacitors are produced with voltage ratings from several volts to scores of kilovolts.

The insulation resistance of a capacitor is determined by the dimensions and the quality of dielectric used. This parameter makes it possible to evaluate the current leakage across a capacitor and to draw a conclusion about the reliability of operation of a capacitor in a certain circuit stage.

The graphic symbol of the capacitor is commonly given in the circuit diagram. In addition, the symbol is supplemented with the Roman capital letter C provided with a numerical or letter index, and the capacitance value. The capacitance from 1 to 10,000 pF is given in picofarads (micromicrofarads), from 10,000 pF up, in microfarads, omitting in both cases the unit of measurement (e.g. 3,300 instead of 3,300 pF). If the capacitance is expressed in integers of microfarads a comma and zero are put after the capacitance value (10 mF—10,0). For capacitances expressed in fractions or integers with fractions of a picofarad the unit of measurement is given (0.5 pF or 7.5 pF).

Variable or trimming capacitors are marked with the minimum and maximum capacitances or with the maximum capacitance only. Electrolytic capacitor symbols are often provided with an indication of their voltage ratios given next to the capacitance number, thus a 5 μF capacitor designed for 450 V voltage is marked 5,0* (450 V).

FIXED CAPACITORS

In these capacitors paper, polystyrene film, mica, ceramics or aluminium oxide are used as dielectric material.

Depending on design, parameters and application, fixed capacitors are subdivided into low- and high-frequency capacitors.

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* In Russian a comma separates an integer from fractions, whereas in English a dot is used instead.

Low-frequency capacitors comprise paper types БМ, БГМ, КБГ, МБГО, МБМ; electrolytic types КЭ, ЭГЦ, ЭМ, ЭФ, ЭТО and others. High-frequency capacitors comprise mica and enamel types КСО, СГМ, КСГ, КС; ceramic types КТН, КТП, КТК, КТМ, КДС, КОБ, КДК, КДО, КДУ; film and metallized-film types ПО, ПМ, ПСО, ПС, МПГ and other capacitors.

The USSR State Standards require fixed capacitors to be manufactured with the capacitances ranging between 1 pF

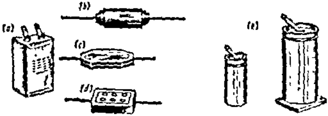


Fig. 1 Fixed capacitors
a—paper, b—film, c—mica, d—ceramic, e—electrolytic

and 2,000 μF. The capacitance marked on the elements is the rated value, whereas the actual capacitance may vary within the tolerance limits depending on the class of accuracy.

Let us consider the principal types of fixed capacitors in detail.

Paper and metallized-paper capacitors. These (Fig. 1*a*) are widely used in modern radio equipment as blocking, decoupling and filter capacitors. In these capacitors paper impregnated with insulant is the dielectric, and metallic foil—the electrodes. Paper capacitors are available in various sizes, and shapes and ratings.

Capacitors type КБГ (paper capacitor, sealed) are sealed into a cylindrical or rectangular metallic casing with glass or ceramic bypass insulators.

Several modifications of the КБГ type are known: КБГ-И in cylindrical ceramic or glass casing, КБГ-М1 and КБГ-М2 in cylindrical metallic casing, КБГ-МП in flat rectangular metallic casing and КБГ-МН in standard rectangular metallic casing.

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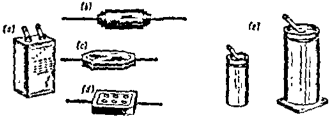


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The demand for heat-resistant capacitors was met by manufacturing the БГМТ type (paper, sealed, small-size, heat-resistant), with either inserted (БГМТ-1) or soldered (БГМТ-2) contacts.

The transistorization of radio equipment has resulted in the development of miniature capacitors such as the БМ (paper, small-size) and БГМ types (paper, sealed, small-size).

Models БМ-1 and БМ-2 are also known with inserted and soldered contacts, respectively. The БМ-1 model is not recommended for application in circuis with voltages below 10 V. БГМ capacitors are intended for d.c. circuits. In the БГМ-1 model only one lead is insulated and in the БГМ-2—two.

Metallized-paper capacitors are a version of paper capacitors. They are manufactured from paper impregnated with an insulant, on which a thin metallic current-conducting film is deposited; they are much smaller in size than usual paper capacitors of similar parameters.

The metallized-paper capacitors comprise a special group of capacitors capable of self-healing after a breakdown. In case of an accidental shorting in some points of the plates the short-circuiting current melts and partially evaporizes the thin layer of metal around the breakdown area burning out the short and restoring insulation between electrodes.

Soviet industry manufactures metallized-paper capacitors of the МБГ type including capacitors of various design and shape, and for different frequency ranges. All capacitors of this type are intended for d.c., a.c. and pulse current circuits.

Heat-resistant capacitors (type МБГТ) designed for operation at temperatures up to 100°C are also available. Miniature capacitors (МБМ) are employed in transistorized radio equipment operating under the same conditions as the previous group.

Film and metallized-film capacitors. Film capacitors (Fig. 1b) employ organic films (sometimes combined with paper) as the dielectric insulation. The films feature high mechanical strength and heat resistance, they are also sufficiently stable against chemical agents, acting during capacitor sealing. The films most commonly used are poly-

styrene, styroflex, polyethylene as well as mylar (polyethyleneterephthalate).

Film capacitors do not differ in design from similar paper capacitors. They may be of a hermetically sealed type or unsealed in various casings; miniature capacitors are also available.

The following types of capacitors are employed in d.c. circuits: ПО (film, unsealed), ПМ (polystyrene, small-size), ПОВ (film, unsealed, high-tension) and ПГТ (polystyrene, hermetically sealed, precision). In d.c. and a.c. circuits capacitors of the ПКГТ type (film, combination, hermetically sealed, heat-resistant) are employed; in d.c. and pulse current circuits capacitors type ФГИ (teflon, sealed, heat-resistant) are used. In d.c., a.c. and pulse current circuits capacitors type МПГ (metallized-film, sealed) and ФГ (teflon, heat-resistant) are used

Mica capacitors. These (Fig. 1c) have high-quality mica as the dielectric interlaid with current-conducting electrodes in the form of metallic foil or a thin silver coating deposited by the burning-in method, or by spraying.

Depending on the design these capacitors are either hermetically sealed or waterproof, this is done with the use of an insulation compound or by a special impregnation technique. Hermetically sealed capacitors using a glass bypass insulator for the leads are also available.

Of these capacitors the following are most widely used: type КСО (mica, moulded) and type КСГ (mica, hermetically sealed). The Soviet industry also manufactures miniature capacitors type СГМ in ceramic casings.

All mica capacitors are intended for use in d.c., a.c. and pulse circuits. Owing to low losses and high resistance of the dielectric, mica capacitors are mainly employed in high-frequency circuits; in other radio circuits they are used as bypass or blocking capacitors.

Ceramic capacitors (Fig. 1*d*), although comparatively recently introduced into radio engineering practice, have already gained wide use. Ceramic capacitors consist basically of a ceramic plate or tube provided with electrodes formed of a metal film (usually silver) deposited at high temperature by the burning-in method. They are notable for low losses at high frequencies, and are extensively used

in the ultrahigh frequency wave range (u.h.f.). These capacitors are not subject to ageing, i.e. their capacitance is always constant with time.

Under certain conditions (high temperature and abrupt changes in mechanical pressure) piezoelectric effects occur in ceramic capacitors. It is known that if a ceramic capacitor acquires piezoelectric properties, it will retain them in future. For this reason potential differences may inadvertently develop and subsequently become a source of interference in tuned circuits with low signal-to-noise ratio. Mechanical overstresses reduce the service life of ceramic capacitors. Experimental data show that service life of ceramic capacitors is inversely proportional to the cube of voltage.

Ceramic capacitors are relatively fragile, they are easily damaged by shocks and vibrations. Available are various types of fixed ceramic capacitors: tubular, disk, base and bypass.

The characteristics of each type of capacitor can be different, as they depend on the ceramic used, production technique, etc. Ceramic capacitors are classified into six groups in accordance with the *temperature coefficient of capacitance* (TCC), each group being marked by a different colour of the whole element or of the marking dot:

	group
TCC not specified	Н (orange)
$(120 \pm 30) \cdot 10^{-6}$	С (dark-blue)
$(30 \pm 30) \cdot 10^{-6}$	Р (grey)
$-(50 \pm 30) \cdot 10^{-6}$	М (blue)
$-(700 \pm 100) \cdot 10^{-6}$	Д (red)
$-(1{,}300 \pm 200) \cdot 10^{-6}$	К (green)

The following types of ceramic capacitors are intended for operation in d.c. and a.c. circuits as tuning, bypass, and blocking elements: КТМ (miniature, tubular, ceramic), КДМ (miniature, disk, ceramic), КТК (tubular, ceramic), КДК (disk, ceramic), КДУ (disk, ceramic, for u.h.f. applications), КДС (disk, ceramic, ferroelectric).

Various types of capacitors КОБ (moulded, ceramic, barrel-shaped) are used in d.c. and pulse current circuits. Various capacitors of the КВКТ type (tubular, ceramic, for high-voltage application) as well as КВКБ (barrel-

shaped, ceramic, for high-voltage application) are employed in tuned, plate, grid and feeder circuits.

Electrolytic capacitors use aluminium or tantalum plates on which an oxide film is deposited that acts as the dielectric, with the electrolyte as the other plate (Fig. 1g). Electrolytic capacitors are made from two layers of foil (one of them oxidized) with paper or fabric impregnated with electrolyte sandwiched between them. The foil and [illegible] material are formed into a roll and placed [illegible] connected to the oxidized foil [illegible] electrode). [illegible] er types in [illegible] These capacit[illegible] and [illegible] high unit capacitance and [illegible] designed for operation in ripple current circuits as filtering elements.

Electrolytic capacitors are designed for operation in ripple current circuits as filtering elements. Under normal operating conditions they are characterized by insignificant, but stable, leakage currents which, in case of overheating, can rise dangerously high and damage the component. Their capacitance is considerably reduced with a decrease in temperature.

Depending on their resistance to low temperatures, electrolytic capacitors are divided into four groups:

Н (not frostproof) . .	temperature range from −10 to +60° C
М (frostproof) . .	temperature range from −40 to +60° C
ПМ (highly frostproof) . .	temperature range from −50 to +60° C
ОМ (exceedingly frostproof) . . .	temperature range from −60 to +60° C

Electrolytic capacitors type КЭ are fabricated in two versions differing in the way of mounting (КЭ-1a and КЭ-1b); electrolytic tubular hermetically sealed capacitors (type ЭГЦ) are also manufactured in two versions depending on the mounting method. The need for miniature capacitors is met by the ЭМ type produced in tubular casings.

A separate group of miniature capacitors is represented by tantalum capacitors. The positive electrodes of the capacitors are made of powdered tantalum. The porous anode surface in combination with liquid electrolyte considerably increases the effective plate area.

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Electrolytic capacitors are designed for operation in ripple current circuits as filtering elements. Under normal operating conditions they are characterized by insignificant, but stable, leakage currents which, in case of overheating, can rise dangerously high and damage the component. Their capacitance is considerably reduced with a decrease in temperature.

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A separate group of miniature capacitors is represented by tantalum capacitors. The positive electrodes of these capacitors are made of powdered tantalum. The porous anode surface in combination with liquid electrolyte considerably increases the effective plate area.

Tantalum capacitors have smaller dimensions and weight (at comparable working temperatures). They can be more advantageously used at high altitudes and are less affected by vibration and humidity, have small leakage current (5-10 mA) and capacitance drift; they also have low inductance and long service life.

TRIMMER CAPACITORS

Trimmer capacitors are used in tuning circuits of radio receivers and other radio apparatus to ascertain accurate alignment. In trimmer capacitors one of the plates is made movable with respect to the other (Fig. 2). Designed for relatively small variations in capacitance, they are *made with an air or solid dielectric.*

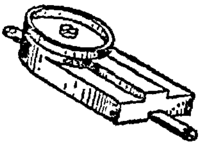


Fig. 2. Trimmer

Air-dielectric capacitors can be with flat or cylindrical plates. The solid-dielectric capacitors most commonly used are ceramic trimmers of rotary flat-plate or cylindrical types.

The trimmer capacitors manufactured by Soviet industry are designated КПК (trimmer ceramic capacitors); they are intended for operation in d.c. and a.c. circuits and are fabricated in four modes: models КПК-1, КПК-2, КПК-3 and КПК-5 are known. The stator of these capacitors is in fact the ceramic base with a thin silver-film sector applied; the rotor is a ceramic disk with a similar sector. The trimmer capacitance is changed by turning the rotor disk.

VARIABLE CAPACITORS

Variable capacitors (Fig. 3) are used when the capacitance is to be changed continuously by varying the amount of meshing between movable and stationary groups of plates (Fig. 3*a*). Widely used in high-frequency tuned circuits, they give high precision of adjustment and low losses. There are also variable capacitors with solid dielectric in which insulating strips are placed between the plates; these are mostly used for adjusting purposes.

Variable capacitors are grouped into four types according to the character of capacitance variation with shaft rotation determined mainly by the following shapes of the plates: straight-line capacitance, square-law, straight-line-frequency, and logarithmic.

Straight-line capacitors with semicircular plates change their capacitance in direct proportion to the angle of shaft rotation. The use of these capacitors is restricted mainly to special measuring instruments. Square-law capacitors

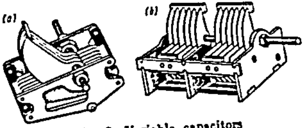


Fig. 3. Variable capacitors
a—single, b—ganged

have a somewhat differently shaped plates enabling them to change the circuit wavelength in direct proportion to the angle of shaft rotation. These capacitors are also seldom used.

A wider application has been found for straight-line-frequency capacitors which enable a linear change of the circuit frequency over the entire range, and for logarithmic capacitors in which the capacitance percentage change per degree of the shaft turn is a constant value in any range area. This provides for accuracy of reading over the entire scale length and considerably facilitates ganging several capacitors on a common shaft.

Broadcast receivers are usually furnished with variable capacitors whose law of frequency variation is close to that of logarithmic capacitors.

Commercial equipment employs gang capacitors in which one, two (Fig. 3b) or three sections are mounted on the same shaft, with air as the dielectric. The minimum capacitance of such capacitors (with the plates brought out) of various types is in the range of 10 to 17 pF, and the

maximum capacitance (with plates moved in) between 450 and 540 pF. The insulation resistance between the movable and stationary plates of the capacitor at any setting of the shaft should be not less than 200 MΩ. For ultrahigh frequencies capacitors are employed with a capacitance varying between 8 and 20 pF.

CHECKS AND TESTS

The most characteristic faults of capacitors are breakdown, shorting, leakage, change of rated capacitance.

Overvoltage may be the cause of a breakdown of insulation resulting in a short circuit between the plates. Short-circuiting, as a result of mechanical action, is more often a fault of variable capacitors. Excessive heating reduces insulation resistance which results in leakage of current. The change in rated capacitance can occur as a result of prolonged operation, particularly at varying temperature.

Less frequent faults listed below are mainly due to mechanical defects, comprising the brushing of rotor and stator plates against each other, longitudinal (axial) and lateral (radial) play in the rotors, current collectors and other structural elements, jerky rotor rotation, absence of lubricant in bearings and step bearings.

Assembly defects are checked by visual examination, after dust, chips, drops of solder and other foreign matter have been blown off the capacitors, particularly from the gaps between the stator and rotor plates. This cleaning (blowing) should be done in a room provided with an adequate ventilation. Then, the electric, mechanical and "climatic" tests should follow, the character and scope of which depend on the purpose and expected operating conditions of the radio equipment.

The basic electric parameters to be tested include:

insulation resistance between the stator and the chassis, if the rotor is electrically connected to the chassis, or between the rotor and the stator, if a ceramic rotor axle is used in the design;

minimum and maximum capacitance; this test should be combined with matching of the sections;

microphonics;

stability of the resistance value of current-carrying electric contacts.

The insulation resistance between the stator and the chassis (if the rotor is electrically connected with the chassis) or between the stator and the rotor (when the latter is not electrically connected with the chassis) should be not less than 1,000 MΩ. The plate spacing should not exceed 0.5 mm and must endure without breakdown a 500 V d.c. voltage.

Radio transmitter capacitors with plate spacing exceeding 0.5 mm are tested for voltage breakdown under a doubled rated voltage, d.c. or a.c. with the mains (50 c/s) frequency. The air gap is tested for electric strength in special cabinets provided with automatic blocking in which the capacitor under test is automatically deenergized when the cabinet door is opened.

The minimum and maximum capacitances must be within the specified tolerances. This test is to be combined with the adjustment (matching) of individual sections of the capacitor so as to obtain an accurate alignment of the capacitance. For this purpose the end plates of all the rotor sections are provided with slits. By changing the air *gap between individual parts of the slit rotor plates and* those of the stator, the capacitance of each section in any given setting of the rotor can be varied. Usually the variable capacitor sections are matched in 6 to 8 points. The number of slits in the rotor plates should correspond to the number of matching points. The sections are matched by means of high-precision instruments.

Slit plates after matching have residual internal mechanical stresses, which give rise to a mismatch with time. These internal stresses can be removed subjecting the variable [illegible] eating in [illegible] oling.

The microphonics is due to acoustical feedback between the loudspeaker and the local oscillator of the variable capacitor. The vibration of the capacitor plates results in frequency modulation of oscillator voltage, causing low frequency oscillations at the radio receiver output.

The microphonics can be partially eliminated by annealing the rotor and stator plates, thus reducing their resili-

ence; also by proper fastening of the plates and application of glue at the points of fastening the plates to the rotor shaft and the stator frame. In variable capacitors it may be avoided by die-casting the rotor and stator.

The tests listed above are to be applied to all capacitors manufactured. Selectively the rated capacitance is checked by turning the rotor 10,000 times from 0 to 180° and back; the deviation value should not exceed 0.25 per cent of the rated.

Mechanical tests include checking the rotor torque, which should be between 250 and 450 g·cm, spring pressure (not less than 60 g), and checking the variable capacitor for vibration and impact strength and wear resistance.

The torque is determined with the aid of a simple device consisting of a rod and a sliding poise; the device is attached to the rotor of the capacitor. The spring pressure is determined with the help of a dynamometer. The vibration and impact strength are tested on vibration- and shock-load testing machines.

The wear test is carried out by means of a mechanical device which turns the rotor shaft either 10,000 complete turns or 10,000 double turns of 180° after which there must be no perceptible play.

The torque and spring pressure tests are made on all capacitors, the other tests being selective.

The "climatic" test determines the effects of temperature and humidity on the capacitor. After subjecting the capacitor to various temperatures, the temperature coefficient is evaluated, from which the condition of the capacitor can be reliably determined. These tests are also selective.

After the "climatic" tests, the condition of the rust-proof coating is checked, and the smoothness of rotor rotation and contact resistance.

2. Resistors

CLASSIFICATION AND CHARACTERISTICS

Two basic groups of resistors most commonly used in radio equipment are compound resistors in which a layer of carbon or metal applied to a ceramic rod or tube is the

conducting component, and wire resistors in which, as the name suggests, a high ohmic resistance wire (for example, manganin) serves as the conducting component.

Compound resistors can be subdivided into two groups: (1) composition resistors; (2) high-stability film resistors.

Composition resistors are manufactured from a material featuring high resistivity and a bonding material. Resistors of the required shape and value are moulded from these two components. They can be made either in the form of a solid conducting body (volumetric construction) or in the form of conducting layers on an insulating base (flat construction). With reference to conducting and bonding materials, the composition resistors are further subdivided into carbon-ceramic, soot-varnish, metal-ceramic, etc.

Film resistors are obtained by depositing a resistive film on the surface of an insulating cylinder or thread. Depending on the type of the conducting material there are carbon- and metal-film resistors.

The stability of resistors to a large extent is dependent on the method of their protection against climatic and mechanical effects. As to the protection technique (and its effectiveness) the resistors are grouped into non-protected, varnished, compounded, moulded with plastics, sealed and vacuum. Varnished resistors are actually non-insulated; this must be taken into account in the process of assembly and wiring.

The symbols accepted in radio engineering for designation of the non-wire resistors reflect their features and consist of three letters. The first one indicates the type of the conductor (К—composition, У—carbon, М—metallized-film); the second letter stands for the type of protection (Л—varnished, Г—sealed, В—vacuum); the third letter pertains to the peculiar features or designation of resistors (for general-purpose resistors: Т—heat-resistant, П—precision, В—high-voltage, М—megohm, etc.). Thus, composition, varnished, high-voltage resistors will be marked КЛВ; metallized-film, varnished, heat-resistant—МЛТ, etc.

Before the introduction of this standard designation system another method of denomination was in use which

nas been preserved for old-type resistors, for instance, BC, TO, СП, etc.*

The conductive component of *wire-wound* resistors is the wire. It should meet a number of requirements of which most important are: high resistivity, low ohmic temperature coefficient, negligible contact emf with copper, high corrosion resistance, high time stability of features, high-quality insulation, high tensile strength, low percentage elongation due to tension, low contact resistance with contact loads from fractions of a gram to several grams (independent of environment and ambient temperature), high wear-and-tear durability in conjunction with other spring contacts, high ductility, enabling small-gauge wires up to 0.02 mm in diameter to be manufactured.

Copper-base alloys (constantans) and chrome-nickel-base alloys (nichromes) are in current use in manufacturing resistive wires. In addition, fixed resistors are very often made of manganin and noble-metal-base wires.

Compound and wire-wound resistors are divided into *fixed* and *adjustable* types.

Fixed resistors are not adjusted whereas adjustable resistors are adjustable over a considerable range of resistance.

Both fixed and adjustable resistors are denominated by their nominal resistance which is marked on the resistor and is expressed in ohms or megohms. Resistors from several ohms to many megohms are in current use. The nominal value of an adjustable resistor refers to its maximum resistance.

The maximum possible variation of the actual valu from its nominal value is specified by the class of precisior Commercial wire-wound resistors are divided into thre classes of precision: (1) with ±5% tolerance; (2) ±10 and (3) ±20%. This means, for example, that for a thir class 10 KΩ resistor its actual resistance may vary betwe 8 and 12 KΩ. Choice of the class of a resistor is governed its function in a circuit. Resistors of the 1st class of pre sion are used, for example, in circuit sections requiri

* The system of resistor designation (in fact, like that of ot radio components) refers to elements made in this country o (*Translator's note.*)

recision of operation. On the other hand, in circuits ich even a relatively large change in resistance has ll effect on the conditions of operation (as, for examn decoupling circuits), 3rd class resistors can be used. ne wattage rating of the resistor is the maximum d.c. a.c. power that it can dissipate over a period of time out substantial change in value. Resistors are made ratings from fractions of a watt to hundreds of watts, le the ratings of compound resistors in common practice 0.12, 0.25, 0.5, 1 and 2 watts. The wattage rating is ermined by the formula:

$$P = U^2/R$$

which P — dissipating power, W
U — voltage drop across resistor, V
R — resistance, ohms.

The actual resistor wattage rating should be somewhat greater (by 30-40%) that the evaluated dissipating power. Thus in case of R = 1,000 ohms, U = 10 V and, hence, P = 0.1 W, a 0.25 W resistor should be taken instead of the 0.12 W one which is the nearest to the value obtained.

The voltage drop across a resistor depends on the resistance value and the power dissipated ($U = \sqrt{RP}$). However, each type of wire-wound resistor is characterized by the rated voltage which, if exceeded, may cause a breakdown of the insulation due to which a disruptive electric discharge (electric arc or sparking) occurs across different parts of the resistor. This is why in choosing a compound resistor, in addition to its value and wattage rating, the rated voltage should also be taken into account.

Thus, for instance, if a BC-0.25 resistor of 1 MΩ nominal value is dissipating 0.25 W power which is nominal for it, the drop of voltage across the resistor will be 500 V, whereas the limiting working voltage for this resistor is only 350 V. Obviously, another type of resistor, say, BC-0.5 of 1 MΩ for 500 V, should be employed, or two 0.5 MΩ series-connected resistors.

Commercial compound resistors cover voltages from 100 to 1,000 V (continuous load). The voltage can be approximately doubled for pulse loads. The permissible voltage is usually in direct proportion to the length of the resistor.

resistance changes with temperature, depending on ...stor type. The amount of change in resistance with ...ange in temperature is called the *temperature coefficient* (RTC), and this commonly does not exceed 0.2% ...C change in temperature for most commercial compo... resistors. For example, if the temperature of a BC-0.25 ...tor (nominal value 1 MΩ and RTC 0.2%) is changed ...20°C, the value will be changed by —4%, i.e. it will be ...uced to 0.96 MΩ. For wire-wound resistors the RTG i... ...gligible and is not taken into account.

When electric current flows across a resistor, together ...ith an orderly (regular) movement of electrons, a chaotic (irregular) movement of electrons also takes place inducing a certain (comparatively small) variable electromotive force (emf) across the resistor terminals. When amplified along with the useful signal, this emf gives rise to a characteristic noise and is known as the resistance noise emf.

Resistance noise is determined by the ratio of the noise emf across a resistor to an applied d.c. voltage of 1 V. ...esistance noise is mostly characteristic for compound resis...ors which are classified into two groups in accordance with this feature: A—for resistors with the noise emf no... exceeding 1 mV/V and Б—with that not exceedin... 5 mV/V.

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To relieve the circuit diagram of superfluous inscriptions, resistance ratings are usually designated in abbreviated form. Thus resistors from 1 to 1,000 ohms are given in integers without mentioning the unit of measurement (e.g. a 350 ohm resistor is designated 350). Resistors from 1 to 100 kΩ (sometimes up to 1 MΩ) are denoted by the number of kilohms and small letter "k" (for example, a 35 kilohm resistor is denoted 35 k). Resistances from 0.1 MΩ up are designated in megohms, not specifying the measurement unit and using a comma and zero after it, if the rating is a whole number (thus resistor of 1 MΩ is expressed by 1,0).

A resistance which is not equal to an integer of ohms is denoted by the corresponding figure with the measurement unit (e.g. 0.5 ohm or 9.5 ohms). If the rating specified on the diagram is an approximation (the exact value being determined in the process of tuning), an asterisk is put at the resistor conventional symbol. An adjustable resistance is denoted by its maximum value only. Frequently the power rating of the resistor is also marked on diagrams by a conventional sign put inside the symbol.

FIXED COMPOUND RESISTORS

Compound resistors are most extensively employed in radio engineering and allied branches. They are smaller, as compared to wire-wound elements, and have negligible

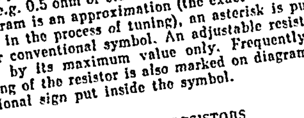


Fig. 4. Fixed resistors
a—type BC: b—type MЛТ

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Any resistor is also characterized by its intrinsic inductance and capacitance, due to which the resistor value depends upon the frequency of the passing current which is often inadmissible. Commercial wire-wound resistors have marked inductance and capacitance and are therefore not used in high-frequency circuits. On the other hand, compound resistors have a negligible inductance and very small capacitance (up to 0.5 pF), which however results in a perceptible change of the resistance at very high frequencies. Thus for BC-0.25 and BC-0.5 resistors the resistance is reduced approximately by 10% at a 10 Mc/s frequency and approximately threefold at 100 Mc/s.

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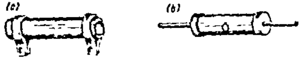


Fig. 4. Fixed resistors
a—type BC; b—type МЛТ

inductance and capacitance of their own, their resistance does not change in a wide frequency range, and, in addition, they are cheap. Such resistors are used in d.c., a.c. and pulse circuits as load, decoupling and damping resistors.

Of the various types of commercial fixed resistances most extensively used are dampproof type BC (Fig. 4a). In conformity with the maximum dissipating capacity, they are

adjustable compound resistors. The isolit base in the BK, TK and CΠ types (Fig. 5*a*) is glued to a cylindrical plastic body. The current-carrying layer of "volumetric" resistor type CΠO is molded into a bow-shaped groove of a ceramic body. Adjustable resistors have three leads: two from the ends of the current-carrying layer and one from the runner whose rotation changes the resistance between the middle and end leads.

Variable resistors (just as fixed ones) are described by the dissipating capacity (between 0.15 and 2 W) and resistance rating (from 470 Ω to 7.5 MΩ).

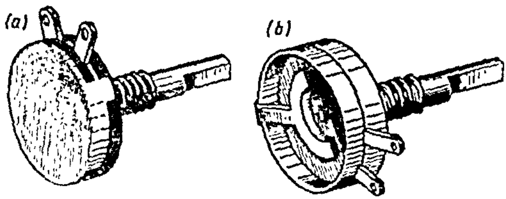


Fig. 5. Variable resistors
a—non-wire CΠ; *b*—wire

A further classification of variable composite resistors is according to the relationship between the shaft angle and the resistance value. Thus, there are linear resistors (Group A), log resistors (Group B), and exponential resistors, (Group C).

The A-group resistances are used in various equipment (for example, in TV sets for line and brightness control, etc.). Generally, they are convenient when the circuit voltage has to be changed in direct proportion to the angle of shaft rotation. The B-group resistances are employed in special cases which require a more rapid change of voltage at the beginning of shaft rotation. On the contrary, the C-group resistances have a reverse character of change, i.e. the change of voltage is less at the beginning of shaft rotation than at the end, which is convenient for volume controls.

WIRE-WOUND RESISTORS AND POTENTIOMETERS

Wire-wound resistors or resistances are extensively used in measuring instruments as range multipliers and shunts. In radio and electronic equipment these resistors

are less frequently used (mainly as load and voltage-dropping ones in heavy current circuits).

The radio engineering industry manufactures wire-wound resistors type ПЭ (wire-wound, enamelled) intended for use in d.c. and a.c. circuits of 50 c/s frequency. The leads of these resistors are made in the form of flexible multiple-strand cords from soft copper wire.

Extensively used are resistors type ПЭВ (wire-wound, enamelled, moisture-resistant) with resistance rating between 5Ω and 56 kΩ and dissipating capacity from 2.5 to 100 W, designed for operation at temperatures from −60 to +100°C. The output terminals of these resistors are made

Table 3

Basic Data of Fixed Wire Resistors

Resistor type	Resistance rating		Dissipating capacity, W	Dimensions	
	from Ω	to kΩ		Dia., mm	Length, mm
ПЭ-7.5	5	5	7.5	10	40
ПЭ-15	5	5	15	14	50
ПЭ-20	2.5	5	20	18	50
ПЭ-25	5	5.6	25	23	50
ПЭ-50	1	15	50	23	90
ПЭ-75	1	30	75	23	160
ПЭ-150	0.9	50	150	30	215
ПЭВ-2.5	43	0.43	2.5	13	26
ПЭВ-7.5	5	3.3	7.5	14	35
ПЭВ-10	5	10	10	14	41
ПЭВ-15	5	15	15	17	45
ПЭВ-20	10	20	20	17	51
ПЭВ-25	10	24	25	21	51
ПЭВ-30	10	30	30	21	71
ПЭВ-40	20	51	40	21	87
ПЭВ-50	20	51	50	29	91
ПЭВ-75	51	51	75	29	140
ПЭВ-100	51	56	100	29	170
ПЭВ-10X	5	0.2	10	14	41
ПЭВ-15X	20	0.22	15	17	45
ПЭВ-20X	20	0.43	20	17	57
ПЭВ-25X	10	0.51	25	21	51
ПЭВ-30X	20	1	30	21	71
ПЭВ-50X	24	1.5	50	29	91
ПЭВ-100X	51	2.7	100	29	170

in the form of brass plates provided with holes for soldering to the external circuit wires.

Also available are resistors type ПЭВ-Х; these are provided with a sliding contact which is used for the adjustment of the resistance.

Basic data on fixed wire-wound resistors are stated in Table 3. Variable wire-wound resistors (Fig. 5*b*) are also used in radio engineering practice.

Potentiometers. Wire-wound potentiometers are used in d.c. circuits as voltage dividers or variable ohmic resistances. They may be single- and multiturn.

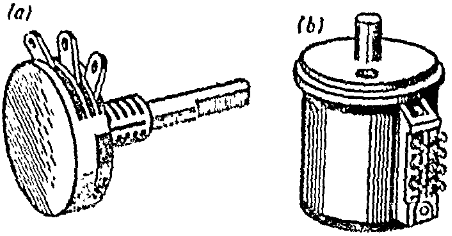


Fig. 6. Potentiometers
a—single-turn; *b*—multiturn

The single-turn wire potentiometer is in fact a device made from a thin insulated resistance wire wound in one row on a former. A slider in the form of a metal strip or wire bent at the end moves on the stripped surface of the wire. As the slider moves over the exposed section of the winding its end comes into contact with the next wire turn before it slips off the previous one, thus maintaining contact all the time. The potentiometer has three leads: two at the ends and the third one connected to the slider (Fig. 6*a*).

In the last few years multiturn potentiometers have come into use; they are small in size in conjunction with high resolution and precision (Fig. 6*b*). The precision of multiturn potentiometers may be as great as one hundredth per cent of the total resistance. A copper wire 1 to 2 mm gauge wound into a resistive element of 3.5, 10, 15, 20, 25 or 40 turns filled with insulating compound serves as the bobbin for the multiturn potentiometer. These potentiometers unlike the single-turn ones are wound with bare (uninsulated) wire.

The change of resistance is due to the variable pitch of winding. The output voltage is taken off by means of a contact arm which moves over the internal surface of the element, simultaneously sliding on the shaft located in parallel with the element axis. The current is passed from the shaft to a collector ring whose axis coincides with that of the element. Thus, instead of the only contact between the resistive element and a movable contact arm, a single-turn potentiometer has contacts: (1) between the resistive element and a movable arm; (2) between this arm and the shaft; and (3) between the arm and a collector ring.

3. Induction Coils

CLASSIFICATION AND CHARACTERISTICS

A great variety of induction coils differing in design and purpose are employed in high-frequency components and circuits of radio equipment. In contrast to resistors and capacitors, induction coils are not produced in large quantities which is due to a great specificity of requirements the coils must meet.

The quantitative and qualitative parameters of a high-frequency coil are determined by its inductance, Q-factor, self-capacitance, and the temperature coefficient of inductance.

Inductance depends mainly on physical characteristics of the coil; the bigger the coil and the more turns it has, the greater the inductance. In addition, inductance is greatly influenced by the insertion of a core and application of a screen. Values of inductance used in radio equipment vary over a wide range, from fractions of a microhenry to tens of millihenries.

Similarly to capacitors, the dissipation of energy in induction coils can be expressed in the loss tangent ($\tan \delta$). However, the quality of coil operation in a.c. circuits is usually expressed by the reciprocal of the loss tangent called the Q-factor (Q_L).

Commonly, coils with medium value of the Q-factor (of the order of 40 to 200) are used for practical work, high Q-factor coils (from 300 up) being employed in special cases (for instance, in tuned circuits and filters).

The turns and layers of the coil make up a capacitance which as a whole can be considered as a capacitor connected in parallel with the coil. This capacitance of the coil impairs its quality (reduces Q-factor and stability, diminishes the range of frequency coverage coefficient in a tuned circuit, deteriorates the efficiency of the coil used as a choke). For

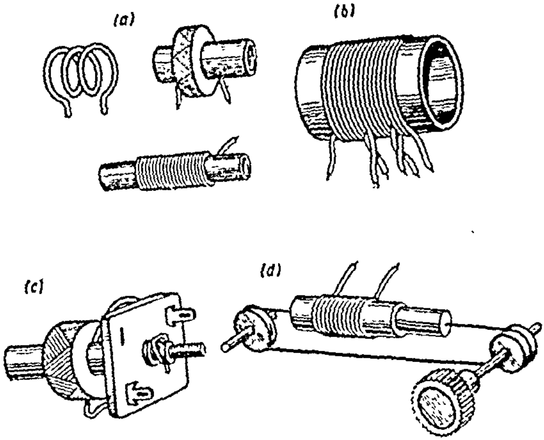


Fig. 7. Induction coils
a—single; *b*—tapped; *c*—with iron-dust core; *d*—variable-inductance coil

these reasons the coils are designed in such a way that they have the least capacitance possible.

The self-capacitance of a coil to a great measure depends on the coil size and the method of wire winding. Larger coils possess greater self-capacitance (coil diameter is more telling). Of minimum capacitance (1 to 3 pF) are one-layer distributed coils, as well as stagger-wound multilayer coils (5 to 30 pF). Coils with the windings divided into separate sections also have low capacitance.

Coil dimensions and, hence, its inductance change with ambient temperature. The relative change of inductance per 1°C is called the *temperature coefficient of inductance* (TCI). Special measures are taken to reduce the TCI. Thus in one-layer coils the formers are made of ceramics, and the coils are wound with wire heated to 80-120°C.

If, for example, the TCI of a one-layer cylindrical coil is of the order of $30 \cdot 10^{-6}$ to $80 \cdot 10^{-6}$, this parameter of a coil with a ceramic former and deposited on it turns will be reduced approximately to $8 \cdot 10^{-6}$-$18 \cdot 10^{-6}$. In tuned circuits the influence of the TCI is diminished by connecting a temperature-compensating capacitor with a negative temperature coefficient of capacitance (TCC).

[illegible]
(for [illegible]
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to another), high-frequency chokes (barring the path to high-frequency currents) and so on. According to design, coils are divided into cylindrical, helical, one-layer, multilayer, air- or iron-cored, screened or unscreened, fixed or variable.

Coils most commonly used are illustrated in Fig. 7.

TYPES OF COILS

The multilayer coil and the cylindrical one-layer types are those most extensively used. Cylindrical windings are employed for coils of low inductance (up to 200 microhenries). They are easy to produce, and have low self-capacitance; the required inductance can be calculated quite accurately (within 3 to 5 per cent).

The conductor is wound into a coil on a thin-walled cylindrical former made from an insulating material. The winding turns are either positioned close to one another or spaced out at a certain interval. To prevent turns from creeping off, the ends of the winding are either fastened with thread or passed through holes in the former. The coil is made of copper wire of 0.3 to 06 mm gauge type ПЭ (enamel-insulated) or ПЭШО (insulated by one layer of silk over enamelled wire).

In winding a coil the number of turns actually wound should be 5 to 10 per cent more than the designed quantity, leaving a margin for the final tuning of the coil by taking off some of the turns which is more handy than to add them.

To increase the Q-factor, the coil former should be made of a low-loss dielectric. Dielectric losses increase with frequency; therefore, in choosing the material for the former

frequency range should be duly considered. At high frequencies good results may be obtained if low-loss materials are used (polystyrene, ceramics).

The coil is mounted at right angles to the chassis (Fig. 8), with the coil turns some distance from the chassis surface. Otherwise the inductance and Q-factor of the coil would be impaired by the eddy currents induced in the chassis by the coil field. Shielded coils should be adjusted after the screen has been carefully secured to the chassis.

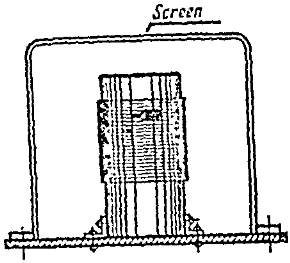


Fig. 8. Screened induction coil

The coil ends are passed through holes in the chassis and enclosed in insulating sleeves. If the coil serves as the inductance of tuned circuit, it is advisable to connect the circuit capacitor to the coil terminal in the immediate proximity to the latter.

Multilayer coils may be either layer- or mesh-wound. The stagger-type winding is also used in multilayer coils. When winding the coil by this method, the wire is wound at an angle to the former axis; at the coil edges the angle of winding is reversed.

The stagger-wound coils can be advantageously used in various circuits, especially as compensating coils in broadband amplifiers, in tuned amplifier circuits, delay line, etc. A feature of these coils is their small size coupled with a relatively large inductance (20 mH and more) and low self-capacitance which is due to this type of winding.

TYPES OF CORES

The use of cores is most effective, making it possible to reduce the overall dimensions of the coils, while retaining a wide range of inductance adjustment, high quality and stability.

The core made from a magnetic material concentrates the magnetic field of a coil, thus increasing its inductance. With the magnetic cores the physical size of coils is reduced

and the Q-factor, sometimes, increased. In addition, the use of a core which can be moved inside a coil makes it possible to change inductance without changing the number of turns, this being an important feature in adjustment of apparatus.

Cores made of iron dust and ferrites are mostly used in radio frequency work.

An iron-dust core consists of fine particles of iron mixed with a "binder" of insulating material in such a way that the individual iron particles are insulated from each other.

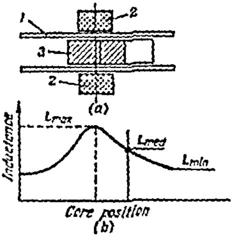


Fig. 9 Cross section of induction coil with magnetic core (a) and inductance versus core position curve (b)
1—frame; 2—coil 3—core

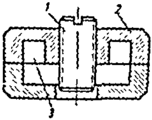


Fig 10 Shell-type core
1—trimmer; 2—carbonyl magnetic circuit 3—space for coil

The ferrite, in contrast to iron-dust cores, is a monolithic material possessing ferromagnetic properties and high resistivity (of the order of 10^{4}-10^{12} *ohm·cm*). Due to this important advantage over metallic magnetic materials, ferrites have small eddy-current losses and can be used as monolithic cores in radio equipment.

A cross section of the "universal" type coil with a core is represented in Fig 9 together with the curve showing the change in inductance as a function of the core position. The maximum inductance is with the core exactly in the

coil centre. In moving the core both sides from the central position, inductance diminishes from L_{max} to L_{min} (equal to the inductance of the coil without a core).

The effective permeability of carbonyl iron cores ($\mu_{eff} = L_{max}/L_{min}$) produced by Soviet industry varies from 1.5 to 2.7 depending on the core type and frequency at which the coil operates.

The carbonyl cores of the СЦР (cylindrical, threaded), СЦГ (cylindrical, smooth), СЦТ (cylindrical, tubular) and СЦШ (cylindrical with pin) types can be used at frequencies up to 25 Mc/s. The core is moved inside the former depending on the design, either by screwing the threaded core into the former (СЦР) or by means of a threaded pin molded into the core. The core should be turned and moved by means of a non-magnetic screw driver, otherwise the screw driver will itself affect the tuning of the circuit.

Magnetic cores can be used both in single- and multilayer-type coils. In addition to the simple cores described, also used are shell-type or "armoured" cores СБ which represent a complete magnetic circuit; they are manufactured from a carbonyl-base compound (Fig. 10). The magnetic permeability of such cores is between 3 and 6 depending on the type and frequency.

The design of induction coils also depends on the frequency range and power of the tuned circuit they are used in. Commonly the coil inductance diminishes with increase in frequency range.

COIL ELEMENTS

The basic components of the coil are the *former*, *winding* and *screen*.

The former is the support for winding. It should be sufficiently strong to provide for rigidity of the winding and to ensure the fastening of the leads and core. The former material selected for the former should meet the requirements of keeping losses in the former dielectric within the specified limits, and also variations in inductance due to the change of geometric dimensions under the influence of temperature, humidity, etc. Formers of the coils used in high-power tuned circuits should have higher voltage break-

down characteristics. Typical constructions of the formers are shown in Fig. 11.

The formers are manufactured from powdered materials, ceramic, polystyrene and other r.f. dielectrics. Split ceramic formers are glued together by the use of glaze and then fired. Ceramic formers are manufactured from r.f. or v.h.f. porcelains and steatite. The formers are provided with internal threading, if the inductance is to be adjusted with the use of iron-dust cores.

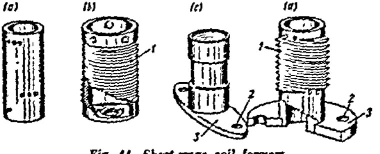


Fig. 11. Short-wave coil formers

a—smooth; b—with grooves for wire; c—with flange and rim, limiting winding width; d—two-piece, with flange; 1—grooves for wire; 2—fastening hole; 3—flange

Grooves cut on the formers contribute to higher induction stability, as they minimize the possibility of accidental shifting of the coil turns. The winding on these formers is made with uninsulated silvered copper wire thus decreasing the dielectric losses.

Ribbed formers illustrated in Fig. 12 are employed for transmitter coils which require a very high Q-factor. Here the wire is in contact only with the former ribs, which considerably decreases the intercoil capacitance and increases the Q-factor. The ribs are grooved on a spiral. The recesses and openings made in the former reduce losses in the material and cut down the weight. In commercial radio transmitting and television equipment extensive use is made of molded powder for fabrication of coil formers.

The winding. Long- and medium-wave coils are commonly wound with litzenwire, whereas short-wave coils employ single-core enamelled wire. Litzenwire is a conductor twisted

from a number (from 7 to 119) of enamelled copper wires of 0.07 to 0.2 mm in diameter. Litzenwire is produced in two types: ЛЕШО (enamel single-silk covered) and ЛЭШД (enamel double-silk covered).

The screen. To reduce the spurious coupling between individual tuned circuits and to reduce the influence of external magnetic fields the induction coils are shielded by closed metallic current-conducting screens.

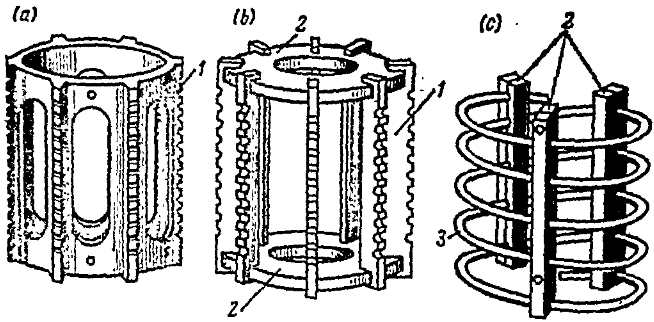


Fig. 12. Ribbed coil formers
a—ceramic (solid); b—assembled, with two flanges; c—strengthened by three ribs; 1—ribs; 2—flanges; 3—wire

Due to the action of the alternating magnetic field eddy currents are induced in the screen which build up a magnetic field in antiphase to the initial magnetic field, due to which the coil external magnetic field is weakened. The reduction is greater with screens of low ohmic resistivity materials. The screen increases the coil capacitance and losses and reduces its inductance. Screens are made of materials with low resistivity, viz. copper, brass and aluminium.

4. Audio Frequency Transformers and Chokes

APPLICATION AND PRINCIPLE OF OPERATION

Transformers and audio frequency chokes are widely used in radio equipment. They are subdivided into *input*, *interstage* and *output* transformers and chokes. The most

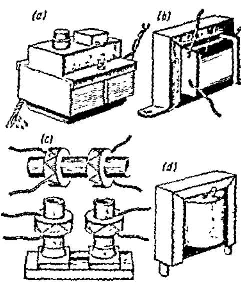


Fig. 13. Power transformer (a), low-frequency output transformer (b); intermediate-frequency transformer (c); low-frequency power choke (d)

up-to-date and extensively used types of transformers and chokes are presented in Fig. 13.

The audio frequency matching transformers THЧ (input, interstage and output) are used with low-frequency transistors in radio and electronic equipment. These transformers are designed for mounting in usual and printed circuits. In printed circuits they are fitted by means of terminal leads and threaded bushes; in circuits with usual wiring—by means of yokes and clips.

Input transformers are used to match the amplifier input impedance with the internal impedance of the signal source. A demerit of input transformers is their sensitivity to stray magnetic fields, due to adjacent power transformers, electromagnetic voltage stabilizers, etc. Stray magnetic fields may give rise to stray voltages at the mains frequency in the case of power transformers or electromagnetic voltage stabilizers, and at multiples of the mains frequency in the case of rectifier filter chokes This interference can cause a.c. hum at the output, for example, at the output of radio

receivers or amplifiers. The proximity of the input transformer to the amplifier output circuits may result in amplifier self-excitation which will interfere with its normal functioning. The interference is reduced by:

(1) shielding the chokes, power and output transformers, using materials of high magnetic permeability;

(2) carefully screening the input transformers;

(3) positioning the axis of the input transformer coil normally to the magnetic flux of the interference source;

(4) correctly positioning the apparatus elements on the chassis (separating the input and output circuits, the input and power transformers, etc.).

The interstage transformers are designed for matching low-frequency transistors. These transformers find application in low-frequency half-wave and push-pull stages. The output transformers are applied in low-frequency transistor circuits with a power rating of 10 mW to 25 W and low-resistance (4.8 and 16 Ω) or high-resistance (150, 300 and 600 Ω) loads.

The maximum amplitude of the a.c. input voltage is 1 V for the input, 5 V for the interstage and 300 V for the output transformers. The d.c. test voltage between the transformer windings and the unit chassis or transformer core must not exceed 70 V. Within the 300 to 10,000 c/s frequency range attenuation at boundary frequencies should not be over 2 db; non-linear distortion factor—below 5 per cent at 400 c/s.

The low-voltage power transformers used in radio equipment are produced in two types depending on their application: plate and filament transformers. Depending on operating conditions, transformers with low- or high-temperature rise may be employed.

Plate transformers have two main and two compensating secondary windings. The main winding is divided into two halves thus enabling the use of transformers in centre-tap circuits. Filament transformers are made with two, three and four secondary windings. The low-voltage power transformers employ split tape shell-type magnetic circuits.

The specific power (power-to-weight ratio) of the transformers depending on their type and rating is between 0.3 and 0.45 VA/g.

Autotransformers ЛАТР-1 and ЛАТР-2 are designed for continuous control of mains voltage. These devices are very convenient for use in the process of assembly and, particularly, adjustment of radio equipment. Their range of voltage control is from 0 to 250 V, nominal primary voltage 220 V, nominal secondary voltage 250 V, scale graduated with an interval of 10 V, efficiency 0.95.

The autotransformer is made in the form of a tubular iron core with a single-layer winding. On one side the winding is stripped of insulation to provide a track for a carbon brush. The carbon brush is moved by a handwheel arranged on the top of the transformer. The handwheel is provided with a pointer moving over a scale graduated within the value of secondary voltage. The autotransformer is enclosed in an iron hexahedral perforated jacket with a terminal panel secured to it.

Pulse transformers form a separate group and are used for the transformation of small duration pulses.

Audio frequency chokes are widely used in rectifier filters for smoothing the pulsations of the current, as well as in low-frequency amplifiers as plate loads of amplifier tubes when a narrow frequency band is to be amplified.

In spite of the difference in the functions of audio frequency and power transformers, the principal physical phenomena in them are of similar nature. Therefore transformers intended for installation in different circuits are similar in design: any of them consists of a magnetic core and windings. Frequently transformers and chokes intended for different applications are made from the same materials.

The magnetic circuit or core is an important element of transformers and chokes. It is made from soft magnetic materials with high permeability, minimum coercive force and small hysteresis losses.

TYPES OF MAGNETIC CIRCUITS (CORES)

Magnetic circuits or cores are divided into *stacked*, *tape-wound*, and *iron-powder cores*.

Stacked cores are assembled from variously shaped laminations or plates made of electrical sheet steels. The

basic lamination shapes are shown in Fig. 14. The assembly patterns are characterized by plate size, power rating, weight, cross-sectional area of the middle limb, mean magnetic path, and overall dimensions, etc.

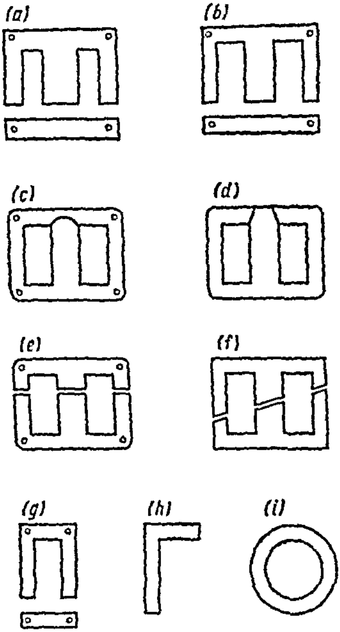


Fig. 14. Types of magnetic circuit laminations

a and *b*—E-I-shaped; *c*, *d*, *e* and *f*—closed-type; *g*—U-shaped; *h*—L-shaped; *i*—O-shaped

Tape-type cores have of late found wide application. To these belong *cut cores* (*C cores*) made by winding a tape into a spiral and cutting it in half (Fig. 15*a*), and *toroidal cores* made from tape lengths of different size, stacked and bent to shape (Fig. 15*b*). The parameters and application of tape-type cores are similar to those of stacked cores. Tape cores of various type are given in Fig. 16. The magnetic characteristics of cut cores are 4 to 10 per cent inferior to those of solid cores due to airgap effect at the butt-joints and the local saturation. However, the former have certain advantages, since they can be produced and, what is more important, assembled automatically. Thus, for example, they may be assembled from coils wound on machines designed for simultaneous winding of 12 and more coils.

Cut cores may be of core- or shell-type; the latter are more widely used. However, the core-type magnetic circuits can be employed advantageously for low-power transformers.

Iron-powder cores are used in r.f. induction coils. They are fabricated from powdered iron and ferrites by means of cold and hot moulding and die casting.

The principal requirements which a core should meet depend on the current and output parameters of a radio unit or device. These requirements are minimum hysteresis

and eddy-current losses, and high magnetic permeability. In addition, stacked and tape-type magnetic cores should

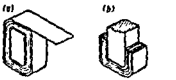


Fig. 15.
a—spiral-wound tape before cutting; b—set of tape lengths bent to shape

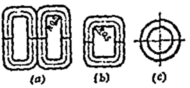


Fig. 16. Tape-type cores
a—shell-type; b—core-type; c—toroidal

have a maximum space factor $K_s = V_{act}/V_{total}$ which is equal to the ratio of the actual volume of iron to the stack total volume.

The required quality of magnetic circuits is ensured by correct choice of material and proper methods of fabrication.

MATERIALS FOR CORES

Cores or magnetic circuits are manufactured from silicon steels, nickel-iron alloys, iron powders, and ferrites. The first two groups of magnetic materials are used mainly for low-frequency applications and the latter two—at high frequencies.

Silicon steels are most commonly used and are applicable at all frequencies from 50 c/s and up to radio frequencies. Depending on application the silicon content varies from several decimal fractions to 4.8 per cent.

The addition of silicon to iron increases the resistivity of the latter several times and perceptibly improves its magnetic properties, though considerably lowering the saturation induction. Silicon also impairs the technological properties of iron, making the latter more brittle. Iron can be cold-rolled, if silicon content does not exceed 3.5 per cent, and stamped and cut when it is below 4.5 per cent.

According to the Soviet Standard transformer steels depending on the percentage content of silicon are divided into the following groups: low-alloyed (0.8-1.8), medium-alloyed (1.8-2.8), high-alloyed, hot-rolled (2.8-3.8), cold-

reduced (2.8-3.5), and superalloyed (3.8-4.8) steels. The properties of these steels to a large extent are determined by the method of rolling.

Hot-rolled silicon steels are used mostly for the cores of chokes, transformers and other elements, operating in audio frequency magnetic fields of high induction. The restriction of frequency ranges is stipulated by an increase in power losses in steel at higher frequencies.

Cold-reduced silicon steels stand out among transformer steels in that their grains are oriented in the direction of rolling, thereby improving magnetic properties. The weight of a core made of cold-rolled steel is 1.5 times less than that of hot-rolled steel.

The silicon steels are characterized by the following magnetic parameters: coercive force 0.15-0.9 oersted, saturation induction (at 20°C) 19,500 gausses, initial permeability 400-1,000 gauss/oersteds, maximum permeability 5,500-60,000 gauss/oersteds.

Nickel-iron alloys (*permalloy*) have also been widely used for magnetic circuits. The magnetic properties of these alloys depend on the nickel content which is from 35 to 80 per cent. The saturation induction of permalloy is not great, ranging from 8,000 gausses for high-nickel steels to 15,000 gausses for low-nickel steels.

High-nickel permalloy of various grades finds application in the manufacture of small-size choke cores, low-current audio frequency and pulse transformers. The saturation induction of the low-nickel permalloy is nearly twice as high as that of the high-nickel alloy due to which the low-nickel alloys can be employed in power transformers and chokes.

The maximum permeability of permalloy is in the range of low field strengths and is many times greater than that of silicon steel, therefore the permalloy is mostly used in magnetic circuits operating with low fields.

A characteristic feature of nickel-iron alloys is their excessive sensitivity to various mechanical strains (compression, tension, bending) which deteriorate the magnetic properties. For this reason permalloy components are annealed after technological operations which can induce stresses in the material.

0.02 to 0.05 mm varies in steps of 10 microns.

Iron powders are made on the base of various soft magnetic materials. Their magnetic properties depend on the material or alloy chosen. The basic magnetic materials are powdered iron obtained by the electrolytic or carbonyl process or reduced from natural ores; permalloy with or without other alloying components; nickel-iron-cobalt and iron-silicon-aluminium (alsifer) alloys, etc.

Most extensively used in industry are iron powders based on alsifer, molibdenum permalloy and carbonyl iron. Alsifer, in addition to its high electromagnetic characteristics, has a distinct advantage over other alloyed materials, specifically over permalloy, in terms of grindability, cost, and availability of raw materials. Carbonyl iron is used to advantage in a wide frequency range from audio frequencies to 200 Mc/s. Carbonyl iron powder consists of the finest spherical grains (1 to 10 microns), obtained by the decomposition of iron pentacarbonyl $Fe(CO)_5$ into carbon oxide and iron. Powders from molibdenum permalloy have the highest initial permeability and their hysteresis losses are below those of alsifer and carbonyl iron.

Ferrites are compounds of the $MO \cdot Fe_2O_3$ type (in which M is the symbol of any bivalent metal) ground and compacted by a special method. They have a number of advantages over iron powders, though cannot completely replace them.

In their composition, ferrites can be single-, double- and multicomponent. They are homogeneous and their properties entirely depend on the composition and caking conditions.

MANUFACTURE OF STACKED CORES

The magnetic circuits with optimum characteristics are obtained by laminating the core; that is by assembling it from separate plates or laminations.

In small-scale production, the cores are hand-made by interleaving plates with insulation until required core thickness is obtained. With this method, separate pieces of the core are butt-jointed.

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A characteristic feature of nickel-iron alloys is their excessive sensitivity to various mechanical strains (compression, tension, bending) which deteriorate the magnetic properties. For this reason permalloy components are annealed after technological operations which can induce stresses in the material.

Nickel-iron alloys are supplied as cold-rolled, untreated sheets and strips from 0.02 to 2.5 mm thick in grades according to the Soviet Standard. The thickness of sheets from 0.02 to 0.05 mm varies in steps of 10 microns.

Iron powders are made on the base of various soft magnetic materials. Their magnetic properties depend on the material or alloy chosen. The basic magnetic materials are powdered iron obtained by the electrolytic or carbonyl process or reduced from natural ores; permalloy with or without other alloying components; nickel-iron-cobalt and iron-silicon-aluminium (alsifer) alloys, etc.

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In small-scale production, the cores are hand-made by interleaving plates with insulation until required core thickness is obtained. With this method, separate pieces of the core are butt-jointed.

The method described provides for better utilization of ce and is employed with L-, U- and E-shaped plates and sed ones. Figure 17*a* gives the pattern for assembling shaped plates. Alternate plates are fitted with openings opposite sides. The "interleaving" assembly is a time-onsuming work, as the plates are placed one by one. The utt-joint between core pieces can be with and without a gap (Fig. 17*b* and 17*c* respectively). The gap is adjusted by layers of treated paper.

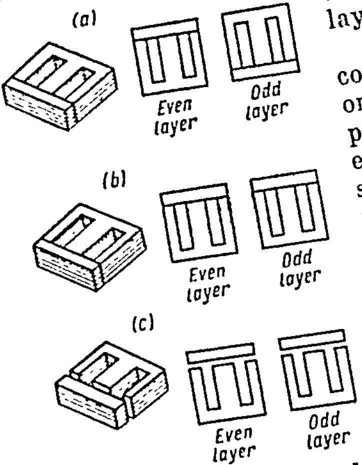


Fig. 17. Types of assembly of magnetic circuits

a—lap-type; *b*—butt-type without air gap; *c*—butt-type with air gap

For greater compactness the core can be squeezed, but only once, in a hydraulic or screw press with a specific pressure not exceeding 40 kg/cm^2. After squeezing, four to six more plates can be added to the core, the last two or three being driven in by a mallet, thus firmly securing the coil on the core.

The cores thus assembled are clamped with tie-rods or studs passed through the holes in the plate corners. The bolts are insulated by resin-bonded paper tubes or insulating paper wrapped around the bolt. If the plates are not provided wit holes, the core is clamped b cardboa brackets, with varnished cambric or insulating placed under them.

In mass and batch production use is made of spec gadgets facilitating and speeding up the assembly of tra formers and chokes. Automatic machines can be used assemble magnetic circuits.

A diagram explaining one of the methods of the me nized assembly of E-shaped and closing plates is show Fig. 18*b*. The finished coil is secured in support *14*, chec that the surfaces *A* and *B* are in one plane at the i stage of assembly. The leads are secured with the a clamp *8*.

The closing plate from feed box *5* (Fig. 18*a*) is supplied into the position shown in Fig. 18*b*. Push-rod *4* of feed mechanism *13* moves this plate (with some delay in time) up to a stop. One E-shaped plate is fed into position as shown in the diagram (Fig. 18*b*), following which push-rod *1* forces this plate into coil *6*. Next, the closing plate is moved in just the same way from feed box *2* (Fig. 18*a*), and push-rod *3*

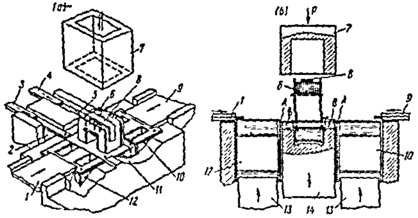


Fig. 18. Device for mechanized assembly of E-I plates
a—general view; *b*—assembly diagram

fits it into the magnetic circuit; push-rod *9* fits an E-shaped plate. A stock of E-shaped plates is found in feed boxes *10* and *12*.

The process continues without interruption until the opening in the coil is completely filled. Part of assembled core *11* is shown in Fig. 18*a*. After each cycle of placing two plates (one E-shaped and the other I-shaped) the base sinks a distance equal to the plate thickness. The assembled core is packed by means of clamp *7*.

Plates of circular or other shape which have no holes for tie-rods are held together with the use of bakelite varnish, БФ-4 cement, etc. Due to the insulating properties of the adhesive substances, the laminations need not be provided with oxide films, parkerized or varnished.

MANUFACTURE OF TAPE-TYPE CORES

The successful manufacture of metallic strips less than 0.1 mm thick has created favourable conditions for the replacement of stacked cores by improved tape-type ones. The cores are generally wound on a semiautomatic machine or a lathe. The fabricated core must correspond to the drawing specifications and the turns of tape be tightly compressed to one another. Possible displacement of turns should be within the limits specified.

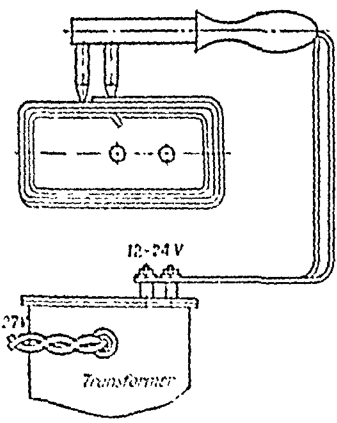


Fig. 19. Fastening of the last turn of a magnetic circuit by point-contact welding

The tape-type cores are insulated with the use of various coatings, of which a substance composed of water glass (807.5 g/l), kaolin from the Glukhovets deposits (150 g/l) and baking soda (42.5 g/l) is considered the best. Water glass has good insulating and adhesive properties, making impregnation in vacuum needless.

To prevent inadvertent uncoiling of a magnetic circuit wound of a tape up to 0.15 mm thick, the end of the last turn is secured by spot welding carried out with the use of a special "welding pencil". As shown in Fig. 19, the insulation is pierced on the last turn only, so as to prevent short-circuiting of the entire component. Depending on the tape thickness, the voltage applied to the "pencil" should be from 12 to 24 V. Owing to their natural rigidity cores made from a tape thicker than 0.15 mm do not uncoil spontaneously, thus making spot welding superfluous.

Upon fastening the last turn, the core is secured in brackets and annealed in a vacuum stove at a maximum temperature below 1,200°C. The annealed cores are freed of brackets and fixtures (avoiding jerks and impacts) on a screw or hydraulic press and impregnated. Cores wound

from electrical sheet steel are impregnated with insulation compound КГМС-2, varnish МЛ-92, cement БФ-4, compound КП-18, varnish 976-1. The magnetic circuits are impregnated in autoclaves or a special impregnating apparatus and dried in thermostats or drying chambers.

5. Switching Devices

PRINCIPLE OF OPERATION

Radio equipment widely uses devices to open, close, or route electric circuits. These, above all, are switches and relays. Circuit-routing may also be accomplished by connectors and valve sockets.

A switch or an electromagnetic relay consists of one or several pairs of electric contacts and of a special arrangement used to make or break these contacts.

The operation of contacts is accompanied by such com-

ometry come into touch. An active medium is always present and each of the surfaces becomes covered with oxide film, the electrical conductivity of which depends on the film properties.

Due to surface irregularities and oxide film, the "effective" contact area composed of the areas of crests on which the insulating oxide film is damaged is small. Commonly it constitutes no more than 0.001 to 0.01 of the total area.

When pressure is applied to the contact surfaces, the crests are deformed and new "holes" in the oxide film appear. Thus the effective contact surface increases and the contact resistance diminishes. This effect does not continue infinitely and the decrease in contact resistance has a limit, and the lower it is, the better the contact surfaces are processed.

The macrogeometry of the contact surfaces is also essential, since equal contact pressures acting upon surfaces of different curvatures would produce different changes of the effective contact area.

The current passing through the contacts is distributed only over the points, constituting the effective area, and therefore the current density reaches great values. The increase in current density brings about the increase of temperature in the contact points up to 700-800°C which results, on one hand, in burning the crests of the surface irregularities and in the increase of the number of holes in the insulating film (thus increasing the effective contact area); and, on the other hand, it creates favourable conditions for the formation of new layers of surface film.

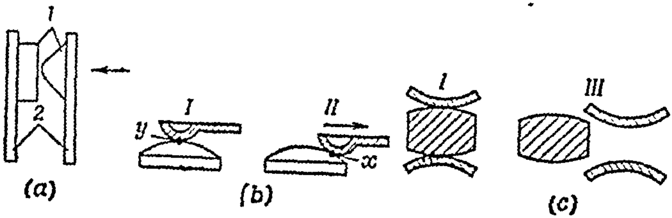


Fig. 20. Contacts

a—compression-type; *b*—friction-type; *c*—cut-in contacts; *1*—contacts; *2*—springs (arrow indicates direction of movement of one of the contacts); *I*—contacts closed; *II*—position of contacts before opening; *III*—contacts open; *y*—contact area; *x*—zone of intensive sparking

The actually measured contact resistance is much greater than the value calculated from the given contact area and properties of the material, since mechanical defects on the area increase the contact resistance tenfold and sometimes even hundredfold.

Operation of the contacts is determined by the physico-chemical, and mechanical properties of the materials. The latter should be resistant to electrical erosion and corrosion which bring about a loss of conductivity in the contact area and might result in a failure of the whole device.

The materials used for contacts should be resistant to wear, easily machined, highly resistant to fusion, and have high thermal and electric conductivity. The materials possessing most of the above properties include platinum, platinum-iridium alloy, gold-nickel alloy, gold-platinum alloy, chemically pure silver, silver-copper alloy, "hard" brass and bronze, tungsten and metalloceramics.

The design and operating conditions of contacts are governed by the following factors: intensity of current

flowing across closed contacts, value of voltage drop across the open contacts, inductivity of the controlled circuit, contact break speed, cooling conditions, frequency of operation and climatic conditions.

The switch and relay contacts are classified into two groups, depending on the character of contact closure in making and breaking, viz. compression (Fig. 20*a*) and friction (Fig. 20*b*) contacts.

The whole cycle of operation of push contacts can be broken down into the following stages.

First stage—contact closing. The contact area is very small and contact resistance is large. With an increase in pressure the metal irregularities are smoothed out, increasing the effective area and decreasing the resistance.

Second stage—the contacts are closed. The process of contact area oxidation due to heating by the current across them takes place. Oxidation will be the more intensive, the greater the contact resistance and the value of current passing across the contacts.

Third stage—contact opening. In the process of opening the contacts the contact pressure is lowered and resistance increased.

At the instant immediately preceding contact opening and after the contacts are parted, an arc or spark occurs between them, due to which the contact surfaces oxidize and burn. With repetition of make and break process, the layer of the oxide film may become so thick that the contact pressure will become insufficient to destroy it and no electrical contact will take place.

With friction contacts the effective contact area and the intensive destruction zone in making and breaking are situated in different places. In addition, the instance of closing is preceded by friction between one contact area against the other resulting in the removal of the oxide film. Friction contacts due to self-cleaning are more reliable than compression ones, though the mechanical wear is much more intensive.

A better contact is ensured by cut-in contacts (Fig. 20*c*) which are a version of friction contacts. The contact in them is established between two contact elements connected in parallel.

All types of contacts are fastened onto spring plates made of an elastic material with high electric and heat conductivity and, if used in switches and relays designed for a great number of commutations, with a high elastic limit. Springs are usually fabricated from various grades of bronze, nickel-silver alloys and brass.

SWITCHES

Switches are intended for making, breaking or simultaneously making one circuit and breaking another. In radio equipment switches are used for cutting in and off, switching over from one range to another and from one mode of operation to another; stopping and locking moving parts in a given position and for remote control purposes.

The principal requirements which the switches must meet are the reliability of electric contact and low contact resistance, optimum contact pressure value, accurate locking in position, a force or moment of given value required to operate the switch, reliable electric insulation and minimum inter-contact capacitance and loss. Also, the switch should not increase significantly the resistance of the electric circuit; the allowable value of switch contact resistance being within 0.01 Ω.

Depending on the number of the circuits controlled at a time, there are two-, three- and multipolar switches.

By design characteristics switches with a small number of poles are grouped into:

slide switches in which the movable contact or contactor slides over the stationary contacts (e.g. wiper-type switches);

push-button switches in which the application of pressure results in making or breaking a circuit;

throw-over or tumbler switches that feature a comparatively short operating time and are put from one position to the other by a throw-over lever (Fig. 21*a* and *b*);

microswitches which are characterized by instantaneous operation when actuated and instantaneous return to the original position when the action ceases;

mains switches in which commutation is achieved by rearranging the position of a plug in a socket.

Multipolar switches include rotary wafer-type switches (Fig. 21*c*), which consist of an insulating base or body with the stationary and movable contacts attached to it. All switches, with the exception of the push-type ones, have a locking arrangement the function of which is to guarantee certain predetermined positions of the movable and stationary contacts with respect to each other.

The proper installation of switches is of great importance. In mounting simple two-pole switches on vertical panels the

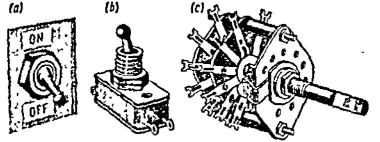


Fig. 21. Switches
a—single; *b*—double; *c*—wafer

"ON" position should always be up and the "OFF" position, down. The "vertical" installation enables commutations to be made quicker and reduces the possibility of brushing against other controls, and allows the work to be performed with lesser mental fatigue.

When several switches are mounted on a panel there [illegible] are used.

Rotary wafer switches must be harnessed in such a way that the values to be controlled increase when the handle is turned clockwise and decrease when rotated counterclockwise. Such wiring reduces possible mistakes.

RELAYS

The electric relays are divided into movable (contact) and static relays according to the principle of operation of the control elements. Static relays affect the controlled

...it by an abrupt (sudden) change of a parameter (inductance, capacitance, etc.) of the actuating element connected to the circuit. Static relays include magnetic, electronic, ...c and other types.

Depending on the type of actuating current, relays are divided into direct- and alternating-current relays. There are current, voltage, power, resistance, frequency, time and other relays, depending on the physical agent actuating the relay.

Relays used in radio electronics and communication equipment must meet the most diverse requirements which usually cannot be satisfied by one universal design. The relays should be of small physical size and weight, and simple and reliable in design, have a sufficient number of control elements (contact springs), high-power commutating capacity, require low driving power (have high sensitivity), short operating and release time, have a possibility to delay considerably the release or operation (for telephone relays).

Some types of multipurpose relays which have found a wide application will be discussed here.

Direct-current electromagnetic relay type PKH (Fig. 22*a*) is used for circuit commutation in various wire and radio communication equipment, automatic and signalling outfit. Under normal operating conditions and non-inductive load on the contacts with 0.2 A current and 60 V d.c. or 110 V a.c. voltage across the open contacts the relay service life (with regular maintenance adjustment) will amount to 10 mln operations. The relay will endure 100 thousand operations under 2 A non-inductive load and 36 V d.c. across the open contacts.

The PKH relay is equipped with two sets of springs each having from two to nine contact springs. Due to the knife-edge-type attachment of the reed and large cross-section of the magnetic circuit, the PKH relay features, in comparison with other relays, small magnetic resistance and high sensitivity.

The heavy-current relay type PKC-3 (Fig. 22*b*) is designed for a.c. and d.c. currents up to 20 A. The relay has only one (closing) contact group; its service life (with readjustment) with non-inductive load on the contacts amounts to ... thousand operations. The power consumed by the ...

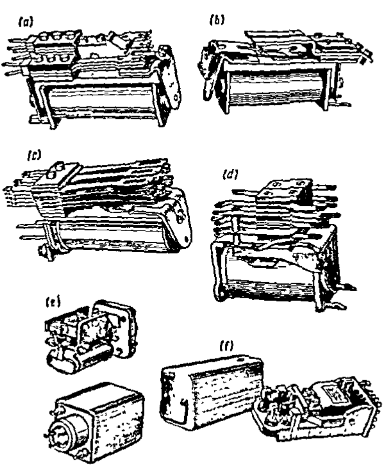


Fig. 22. Relays

a—electromagnetic type PKH; b—heavy-current type PKC-3, c—miniature type PKM, d—miniature, control type PMY; e—sensitive, electromagnetic, double-coil, sealed type РДЧГ; f—polarized

coil is 5 W. The breaking power capacity of the relay contact system under active load is 2 kW with alternating current and 1 kW with direct current (maximum breaking current is 20 A).

The PKC-3 relays are designed to operate with 24, 48, 60 and 100 V d.c. actuating voltage. Its silver contacts are capable of breaking a current of up to 20 A.

Miniature relays type PKM (single-coil, round, direct-current) (Fig. 22*c*) are intended for operation in various wire and radio communication equipment, automatic and signalling devices.

Under normal temperatures and humidity not exceeding 80 per cent their service life amounts to 50 mln operations (at 0.2 A non-inductive load and 60 V voltage).

The PKM-type relays are produced in different versions: they can be normal and slow-release, have one- and two-winding coils, and from 2 to 15 contact springs. The operating time of these relays varies from 4 to 30 msec, the release time—from 5 to 20 msec and 70 msec (for slow-release relays). The sensitivity of the PKM-type relay (with one closing group) is 62 mW. The maximum power consumed by one coil does not exceed 3 W (1.5 W—rated value). The contact package consists of one to three groups of 2 to 5 springs each.

The control, miniature, electromagnetic relays type PMУ (Fig. 22*d*) operate from d.c. sources and are designed for commutating of electric circuits in stationary, portable or mobile, automatic, signalling and communication equipment. The service life of the PMУ-type relays is not less than 100 thousand operations under 1 A non-inductive load on the contacts at 27 V d.c.

The PMУ-type relays are manufactured in the single-winding mode only, with 2 to 12 contact springs, grouped for closing, breaking and switching duties. The total number of groups is from 1 to 4. The springs are fitted with silver contacts.

The d.c., two-coil, sensitive, electromagnetic, hermetically sealed relays РДЧГ (Fig. 22*e*) are used in communication equipment, signalling circuits and automatic apparatus operating under severe climatic conditions. The maximum current for the relay is 0.2 A in case of non-inductive load and short-time operation, and 0.4 A for continuous operation with arc suppression (voltage is 27 V).

The relay service life is 100 thousand operations. The device can endure 10,000 impact overloads up to 4 g at 80 shocks per min. The relays are fabricated with a winding and a switching contact groups. The two coils are connected with a jumper. The relay armature is secured on axles in

step bearings; in operation it turns, closing the pole shoes. The relay sensitivity is very high, since the magnetic circuit is made of permalloy and the armature movement is small.

The polarized relays type РПБ (Fig. 22*f*) in their design, classification and general operating data as well as in the outline and installation dimensions match the polarized relays of the РП type and are interchangeable with them.

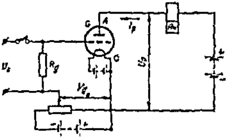


Fig. 23. Electronic relay circuit

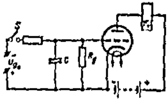


Fig. 24. Simple electronic timer circuit

The ceramic bridge in the РПБ type is replaced with a alumin one which has the coefficient of extension equal to that of the body and former—the factor contributing to stable relay operation.

The electronic relay is a device consisting of a usual electromagnetic relay and an electron tube, acting as an amplifier.

The principle of operation of the electronic relay is illustrated in Fig. 23. With plate voltage equal to U_p, a plate current I_p will flow through the winding of the [illegible] contacts will be open, [illegible] to the control grid G [illegible] it to be less than the [illegible] *he control circuit and* relay contacts are not shown.

If a positive (with respect to cathode) signal voltage U_s is applied to the resistor R_g, the negative voltage on the grid will reduce and the plate current increase becoming greater than the relay operating current; then the relay contacts will close. For this increase in the plate current

a negligible value of the signal voltage U_s is required, since the electron tube possesses a capacity to amplify the signal applied to the grid to a great extent. When the voltage U_s is removed, the plate current will reduce and the relay open again its contacts connected to the controlled electric circuit.

The electronic time relay is used when it is necessary to have a definite time delay between the instance of signal application (closing and opening of the signal contacts) and the instance when the electromagnetic relay operates or releases. The use of the electronic time relay makes it possible to obtain time delays from milliseconds to about 30 seconds.

The relay differs from a usual electronic relay in that it has an additional capacitor C in the grid circuit of the tube (Fig. 24). With contact S closed the capacitor is charged to a negative voltage U_{g0} which cuts off the tube. When the contact opens the tube grid negative potential gradually diminishes, as the capacitor discharges across the resistor R_g. When the tube "opens" and its plate current rises to a value sufficient for the electromagnetic relay to operate, the relay contacts will either close or open the control circuit.

The greater the capacitance C and the resistance R_g, the greater is the operating time; however, the choice of large values of C and R_g is restricted by the leakage resistance in the tube grid and capacitor. The resistance R_g should not be over 5 to 10 MΩ and the capacitance C—more than 10-20 μF. The maximum attainable delay is limited to a score or two of seconds.

The thyratron relay can be used to control high-power processes without additional electromagnetic relays. The thyratron fires at a certain voltage drop across its electrodes which is called the firing potential U_f. The firing potential depends both on the design and physical properties of the thyratron relay and on the voltage (U_g) on its grid. Thus the moment of the relay firing can be controlled by changing U_g.

A schematic diagram of the thyratron relay is presented in Fig. 25. If the control voltage U_g is absent or insufficient, the relay is "dead" and no current is passed through

resistance R. On reaching a certain critical value $U_{g\,cr}$ the relay fires, its resistance becomes insignificant and current passes through resistor R. To return the circuit to its initial condition, the source voltage U_a should be switched off or reduced.

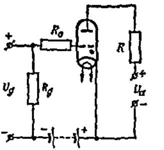


Fig. 25. Simple thyratron relay circuit

The photoelectronic relay usually consists of the illuminator, photoelectric pickup, photocurrent amplifier and output electromagnetic relay. The illumination element contains a source of light (incandescent lamp) and optic elements which form a narrow beam of light. The photorelay pickup receives the light beam and concentrates it on the photoreceiver light-sensitive surface.

In most cases the photoelectric currents are amplified by means of electronic amplifiers since they possess stable

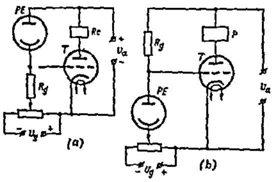


Fig. 26. Photoelectronic relay
a—circuit operating upon lighting; *b*—circuit operating upon darkening

characteristics and ensure accurate operation of the photorelays even under severe operating conditions.

Simple photorelay circuits with a vacuum photocell (PE) and electron tube (T) d.c. amplifier are represented in Fig. 26*a* and *b*. These circuits differ only in the method

of connection of the photocell. The photorelay in Fig. 26*a* operates upon lighting the photocell; that in Fig. 26*b*—upon darkening it.

Upon lighting the photocell, the photoelectric current builds up a voltage drop across the resistor R_g which in the first case reduces the negative bias on the tube grid and in the second case increases this bias. The resistor R_g is selected so as to ensure the required value of plate or anode current in the electronic tube with a given value of photoelectric current.

PLUG-AND-SOCKET CONNECTORS

Plug-and-socket connectors are used in radio equipment for connecting individual units and subassemblies. Low-frequency energy is fed through multicontact low-voltage and high-voltage (hermetically sealed and non-sealed) connectors.

High power is transmitted via special plug-and-socket connectors which are either symmetrical or coaxial. Inside a unit power is distributed between the individual elements via inter-unit flat connectors The connectors consist of a pin part fitted directly to the unit and a socket part fitted to a flexible cable or to the subassembly.

The force required for plugging in or pulling out the connector differs depending on the number of contact pairs, amounting to 10 kg and more. The contact resistance of each pair must not be more than 0.01 Ω. The insulation resistance between individual contacts as well as between any contact and the former should not be below 1,000 MΩ under normal operating conditions and be able to bear the specified a.c. voltage. High-frequency connectors must, in addition, have insulation with low high-frequency losses.

Non-sealed connectors type PШ are intended for connecting various electric equipment to the power mains of up to 500 V a.c. These connectors are intended for continuous duty at ambient temperatures from —15 to +35°C and air humidity up to 70 per cent.

Connectors of this type should not be used:

in places not protected against the penetration of water, oil and emulsions;

in media containing acrid gases and vapours in concentrations destructive to metals and insulation;

in explosive media;

in media saturated with current-conducting dust;

under vibration and shocks.

The connectors are manufactured with different numbers of pins (two-pin, three-pin and five-pin); they can also be with or without a grounding arrangement and can be either attached to or built into a device.

Connectors of PШ type consist of a plug and a socket; never should the plug be disconnected from the socket when the circuit is under load.

The conventional notation of plug connectors explains their design features. Thus in [illegible] fitting diameter, П for the shape of the socket joint (straight), 1 stands for the number of contacts, Э for the type of cable (shielded), Ш for the type of contact in the block (pin), 4 is a conventional notation of the contact combination.

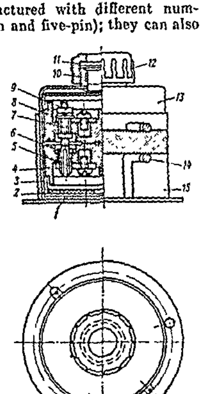


Fig 27. Plug-and-socket connector

The socket of this type of connectors consists of plastic block *4* (Fig. 27) with four sockets *6* and clamps *5* provided in it. The block is enclosed in metallic housing *1*. The cable lead is passed into the socket through a hole 18 mm dia in the housing bottom. The block is secured in the housing by means of two screws *14*. The current-carrying elements are insulated from the housing by means of circular spacer *3* and washer *2*.

For smaller elements (resistors, capacitors, semiconductors) the lugs can serve as mechanical fasteners. The shape of the lug should enable the wire or band-type leads from the parts to be easily and reliably soldered (or unsoldered).

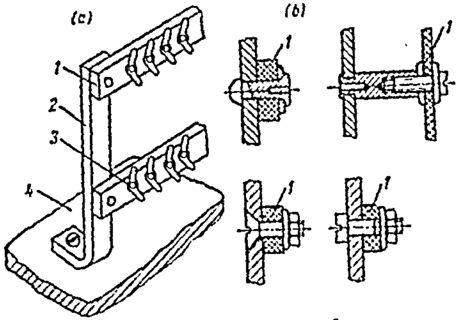


Fig. 29. Wiring panels
a—general view; *b*—fastening of plates

Usually each external wire is soldered to a special point (lead) provided on the lug. In most cases there are two leads on a lug. The lug type and method of its fitting are chosen in accordance with operating requirements.

TUBE HOLDERS

Along with tube holders produced as a part of the tube socket, separate tube holders are also employed.

Tube holders may be of various shapes and designs. Thus tubes with 27, 32, 34.5 and 38 mm base can be secured by holders made in the form of a plate spring (Fig. 30*a*) and fastened with the same screws used for securing the tube socket to the chassis. Four-point lugs on the inner side of the springy ring will firmly hold the tube in place during vibration.

Another tube holder is illustrated in Fig. 30*b*. It is provided with stand *3* and holding vane *1* which engages the tube base shoulder *2*. The stand is attached to chassis *4* by means of a nut and a springy check washer. After the tube has been inserted into the socket, the holding vane is put on the upper shoulder of base *2* and pressed by the nut as required.

Tube holders with tubular stands similarly secured to the chassis and provided with a captive ring which holds the tube by the bulb (envelope) top are also in common use.

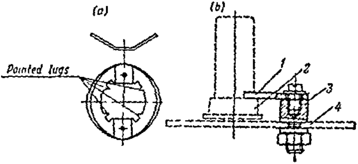


Fig. 30. Tube holders
a—circular plate-type; b—with hold-down vane

FUSE HOLDERS

Reliable protection of radio equipment elements against excessive currents is ensured by different types of protective devices of which fuses are most commonly used. A fuse

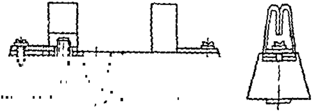


Fig. 31. Open-type fuse holder

comprises a thin metallic strip or wire (fusible link) whose thermal stability has been reduced. The fusible link is enclosed in a glass, ceramic or plastic tube with metallic cap outputs (in good contact with the link) at the ends.

An open-type holder for tubular fuses, such as is illustrated in Fig. 31, is located in accessible places inside the unit. For ease of maintenance these holders should be arranged

he front panel under a detachable protective cover.
n one or several holders for spare fuses are arranged
he same panel with the operating ones.

7. Shock Absorbers and Chassis

SHOCK ABSORBERS

In operation, radio equipment, especially mobile, is
subjected to vibrations and impacts. The effects produced by
them are reduced by shock absorbers in the form of mechan-

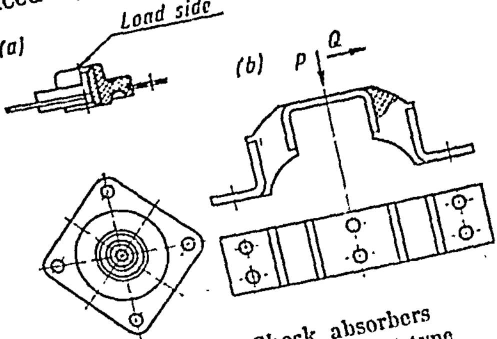


Fig. 32. Shock absorbers
a—metal-rubber; b—bracket-type

ical links mounted between the equipment affecting v
tion and the object subject to it. With a correctly sel
shock absorber, the apparatus will be much lesser in
affected than the object itself.

Two types of shock absorbers are employed in
equipment: metal-rubber and bracket-type.

Metal-rubber shock absorbers (Fig. 32*a*) are used to
the apparatus against vibrations and impact effects
shock absorbers are advantageously used at temp
from −45 to +80°C. The rated load with a shock
stroke (deflection) of 1.6 mm, depending on the shoc
er type, is between 0.45 and 15.75 kg; the limit
load is from 28 to 150 kg. Their residual deforma
a short-term (30 sec) application of a threefold
does not exceed 10 per cent of the stroke meas

rated load. The shock absorbers under nominal load withstand vibrations of 50 c/s frequency and 10 g acceleration during 100 hrs.

Bracket-type shock absorbers (Fig. 32*b*) are serviceable at —40 to +60°C temperatures. The shock absorber deflection in the direction of force *P*, equal to the rated load, is between 4 and 6 mm.

The deflection due to force *Q* does not exceed that affected by force *P*.

Proper operation of the shock absorbers, provided the type is correctly chosen, is also dependent on their location, which is selected on the basis of weight, position of the centre of gravity of the unit, frequency and amplitude of vibrations or magnitude and duration of impacts.

CHASSIS

The chassis is the basic part of any electronic device and is used for mounting electron tubes, resistors, capacitors and other components. Flat-type panels from sheet metal (steel or, more often, duralumin) are in common practice. The use of sheet material provides sufficient rigidity of structure, required thermal insulation, and good electric and magnetic shielding.

Heterodyne or similar circuits are assembled inside box-like chassis so as to protect them against stray couplings with elements of the apparatus. As the solid metal is noted for good thermal and electrical conductivity, the heat-radiating components (vacuum tubes) are mounted on one side of the chassis, whereas those easily influenced by a change in temperature (e.g. capacitors, induction coils and resistors)—on the opposite side.

The chassis design and configuration depend on the type of the apparatus in which it is used. An important factor in placing components on the chassis is whether the equipment is stationary or mobile.

The variety of chassis shapes may be reduced to two principal types: box-type and flat chassis.

The box-type chassis is a bottomless box made from thin sheets. In a number of cases a bottom plate or cover (or casing) is used to provide an additional protection

dust and mechanical damage as well as additional shielding. The chassis is a tetragon in plan. The radio tubes and heavy or large-size parts (transformers, induction coils and large capacitors) are arranged on the top of panel *2* (Fig. 33*a*) and smaller parts and most of the connecting wires are located on bottom side *3*. The rigidity of the panel is ensured by bent edges *4* which at the same time serve as supports.

Usually, this horizontal panel is mechanically connected to a front panel or vertical wall *1* on which all the controls

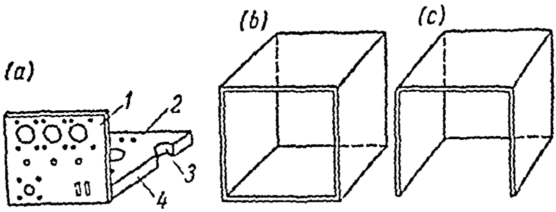


Fig. 33. Simple chassis (*a*); five-wall (bottomless box) (*b*); four-wall (*c*)

are arranged. The chassis of this type can be slid inside a five-wall casing schematically illustrated in Fig. 33*b*. In other cases a cover-type enclosure (Fig. 33*c*) is used which is placed on the chassis from above. From below the chassis is sometimes closed with a bottom sheet.

Box-type chassis can be mounted on racks and connected to other units by means of plug connectors. In this case the chassis are moved into racks along slides, and the front panel is bolted to the rack.

Flat chassis is a metal sheet usually somewhat thicker than that used for box-type chassis. The sheet is trimmed to fit the inter-rack space and holes required for wiring are punched. Tubes and large-size parts are mounted on one side of the chassis, the opposite side being used for resistors and other small components.

This type of assembly is ideal for dissipation of generated heat and provides good access to the elements in servicing. Flat chassis are used in radio equipment intended for control of various industrial processes.

Flat chassis can be mounted vertically in a cabinet thus making the components easily accessible through

rear doors. A U-shaped chassis, a variety of a flat chassis, is widely used in radio equipment. Supporting flanges in this type are formed by bending down the side edges. Two U-shaped chasses joined together form an H-shaped chassis which is exceptionally rigid and space-saving.

8. Decorative Parts

CONTROL KNOBS

Most of the control and adjustment elements have shafts extending through the front panel. For handy operation the shafts are equipped with plastic knobs.

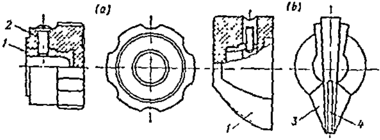


Fig. 34. Knobs
a—plastic; b—"beak"-type

A plastic control knob with molded-in metallic bush *1* is shown in Fig. 34*a*. The knob is secured to the shaft by screw *2*.

A "beak"-type knob, illustrated in Fig. 34*b*, is small and convenient for gripping. The pointed end *3* of the knob with radial groove *4* serves as an indicator of the knob position. If the shaft is to be turned several revolutions, a handwheel with a handle is more convenient than control knobs. After a rough adjustment obtained by turning the handle, fine tuning is effected by rotating the wheel (which has a series of ridges or knurls to aid gripping).

CASES

Cases (cabinets) of commercial radio equipment (specifically radio receivers and TV sets) are usually made of wood or plastics.

As a result of temperature and moisture effects, the wooden cabinets might be warped or twisted from the original shape, and cracks might appear. Therefore the cabinets of receivers or TV sets are commonly made from plywood consisting of several layers of shelled birch-tree veneer sheets glued together with bakelite or other resin.

To prolong the service life of wooden cabinets, they are varnished and strengthened by fitting metal angles or strips at the corners inside them.

Plastic cabinets are made by hot pressing different kinds of thermosetting molding powders.

9. Vacuum Tubes

CLASSIFICATION AND CHARACTERISTICS

Vacuum tubes are extensively used in radio-electronic apparatus; they include:

Receiving tubes designed for operation in radio-frequency (up to tens of megacycles per sec) amplification and conversion circuits. A special group of high-frequency tubes includes wide-band amplifier tubes used in television, radar, multichannel telephone systems, etc.

Oscillator tubes used in oscillators and power amplifiers in high-frequency (up to 20-25 megacycles per sec) circuits as well as medium- and low-frequency amplifier circuits.

Microwave tubes have also found wide application. Modern radio equipment utilizes the following microwave frequency bands: Very-High Frequency (VHF) or metre waves (30 to 300 Mc/s), Ultra-High Frequency (UHF) or decimetre waves (300 to 3,000 Mc/s), Super-High Frequency (SHF) or centimetre waves (3 to 30 Gc/s) and Extra-High Frequency (EHF) or millimetre waves (30 to 300 Gc/s). The frequency bands thus designated include the lowest and exclude the highest frequency cited.

Klystrons, magnetrons, travelling-wave and reflected-wave tubes are used as power amplifiers or high-frequency oscillators in the microwave band. Input travelling-wave tubes find application in radar and relay system receivers. High-power travelling-wave tubes find application in various transmitters as output stages.

Cathode-ray tubes for oscilloscopes and radar indicators as well as for televisor kinescopes.

Receiving tubes are most extensively employed of all vacuum devices and are available in a great number of types. According to design they may be classified as follows:

vacuum tubes containing one tube system inside the envelope (diode, triode, pentode and so on);

dual tubes with two similar tube systems in one envelope (double-anode kenotron, double diode, double triode and so on);

combination tubes containing several different tube systems in one envelope and usually having one common cathode (diode-triode, double diode-triode, diode-pentode, diode-hexode, etc.);

directly heated tubes in which the filament is at the same time the source of electrons (cathode);

indirectly heated tubes in which the cathode, emitting electrons, is insulated from the filament which is solely its heater.

Tubes are manufactured in various shapes and sizes and with different envelope materials.

Metal tubes (Fig. 35*a*) usually have a metal envelope and an eight-pin plastic base with an aligning lug (key) in the centre. Glass tubes (Fig. 35*b*) have a glass envelope and a plastic eight-pin base with an aligning lug in the centre. Bantam tubes (Fig. 35*c*) have output pins secured right in the tube glass bottom; microminiature tubes (Fig. 35*d*) have a cylindrical or flattened all-glass bulb.

[illegible] with electrode lea[illegible] pass through a t[illegible] as through its top and bottom. Lock-in tubes (Fig. 35*f*) feature a glass bulb enveloped by a metallic base (shield) with an aligning lug in the centre. The lug end has a circular groove, which, when caught by the spring of the socket, provides locking the tube.

Disk-seal tubes (so-called lighthouse tubes—Fig. 35*g*) have a glass envelope and a plastic eight-pin base with the aligning lug in the centre. The electrode leads are in the form of metallic disks soldered to the stepped envelope.

A special class of microwave tubes is composed of disk-seal metal-ceramic tubes. These tubes are employed as oscillator and amplifier devices throughout the whole spectrum of microwave frequencies. Metal-ceramic tubes feature high operating temperatures and great design rigidity as well as close tolerances of electrical parameters. These devices are triodes (both low- and high-power) and tetrodes

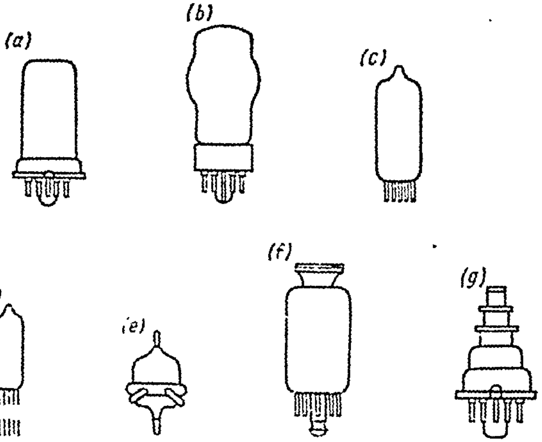


Fig. 35. Vacuum tubes

a—metal tube; *b*—glass tube; *c*—bantam all-glass tube; *d*—microminiature tube; *e*—acorn tube; *f*—lock-in tube; *g*—disk-seal tube

(high-power VHF and UHF) and as a rule are employed in special circuits with coaxial cavities.

Other types of microwave tubes, such as multicavity klystrons and travelling-wave tubes are now manufactured utilizing the advantages of metal-ceramic technology.

An example of pin numbering of tubes with the aligning lug on the base is provided in Fig 36*a*. The pins are numbered clockwise starting from the lug. The lug obviates errors in inserting the tube into the panel. The pins are conventionally shown by circles with the sequential numbers inside. The diagram of the base makes it possible to determine the connection of the pin with a required tube electrode.

An example of a bantam tube electrode pin numbering is illustrated in Fig. 36*b*. Here the base is also viewed from

low and the pins are numbered clockwise as in the previous case. A larger spacing between the first and the last pins is provided to obviate errors when fitting the tube.

Tubes are characterized by the following parameters:

Transconductance S shows the change (in milliamperes) of the plate current caused by the change of the control grid voltage by 1 V, the voltage of the plate and of other grids (on multielectrode tubes) remaining constant. Transconductance is expressed in milliamperes per volt (mA/V).

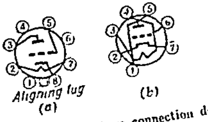


Fig. 36. Examples of tube base connection denotations
a—with a base lug; *b*—bantam

With loaded plate circuit the plate current changes to a smaller degree and the actual transconductance value under these conditions (dynamic transconductance) is less than S.

Internal resistance R_i shows the amount of plate voltage change required to induce 1 mA change of the plate current, the voltage on the control grid and other grids (in multielectrode tubes) remaining constant. The value of R_i specifies the internal resistance of the tube as an a c. generator and is expressed for receiving tubes in kilohms

Amplification factor μ shows how many times the effect of 1 V grid voltage is greater than that of 1 V plate voltage. The μ factor shows the voltage amplification which could be obtained working into a very high load resistance, when the tube internal resistance could be neglected.

Conversion transconductance S_c is often needed for frequency conversion tubes; it shows the intermediate frequency current (in milliamperes) which is induced in the plate circuit when a 1 V signal is applied to the con

Equivalent noise resistance R_n is a resistor on whose terminals at room temperature a noise voltage equal to the tube noise voltage (reduced to the grid circuit) is obtained.

Q-factor is a parameter, characterizing the wide-band amplification properties of a tube.

NOTATION

The tube notation system employs four elements marked either on the metal or glass bulb.

The first element:

for receiving tubes—the number indicating the filament voltage in volts (approx.); for oscillator UHF tubes—letters ГУ; for cathode-ray receiving and oscilloscope tubes—the number stating the screen diameter or diagonal in centimetres;

for stabilivolts (gas-filled voltage stabilizers)—letters СГ;

for barretters (current stabilizers)—a number indicating the stabilization current in amperes.

The second element:

for receiving tubes—a letter specifying the type of the tube, viz.:

diodes	Д
dual diodes	Х
triodes	С
dual triodes	Н
triodes with one or two diodes	Г
remote cut-off pentodes	К
screen grid sharp cut-off pentodes	Ж
frequency-converter tubes with two control grids	А
output pentodes and beam-power tubes	П
pentodes with one or two diodes	Б
tuning indicators	Е
kenotrons	Ц
triode-pentodes	Ф
triode-hexodes	И

for oscilloscope tubes and kinescopes with an electrostatic-deflecting system—letters ЛО;

for oscilloscope tubes with an electromagnetic-deflecting system—letters ЛМ;

for kinescopes with an electromagnetic-deflecting system—letters ЛК;

for stabilitrons—a figure giving the serial number of the device type;

for barretters—letter Б.

Oscillator tubes have no second element in their marking.

The third element:

for receiving and oscillator tubes and cathode-ray tubes—the figure giving the serial number of the device type;

for stabilivolts—a letter which has the same meaning as the fourth element for receiving tubes;

for barretters—two hyphenated numbers giving the voltage of the beginning and end of stabilization in volts.

The fourth element:

For receiving tubes—a letter characterizing the tube construction, viz.:

all-metal tube	no designation
glass tube	С
bantam tube	П
miniature tube up to 10 mm dia	Б
miniature tube up to 6 mm dia	А
"acorn" tube	Ж
lock-in tube	Л
disk-seal (lighthouse) tube	Д

FEATURES OF TUBE APPLICATION

The reliability of vacuum tubes depends not only on [illegible]

in

nd

The causes of failure can be divided into two main groups. The first group comprises mechanical damage of the tube parts—burning-out of cathodes and heaters; damage of fastening of the tube electrodes to the leads; short-circuiting between the electrodes caused by deformation of the electrodes or by foreign current-conducting particles; cracks in the bulb and in the tube base. The second group comprises changes of the electrical properties of the tube resulting in deterioration of tube characteristics.

Radio equipment adjustment must ensure normal operation of a tube. The electrical parameters of the elements must be in full compliance with technical specifications

The following are the most important parameters: minimum voltage between cathode and heater, nominal filament voltage, admissible electrode currents, power dissipation on the electrodes, permissible resistance value in the control grid circuit, operating temperature range, mechanical loads.

Particular care is given to reliable fitting and electrical contact of the tube to its external circuit. The pins of the tubes should be straight and have no traces of corrosion. The straightness of pins is checked by means of a special gauge. Pins, bent due to negligence in handling or unsuccessful attempts to insert the tube, must be discarded.

In fitting a tube into a socket it should not be rotated about its axis for aligning the tube pins with the socket jacks. The tube socket should be arranged so as to provide proper fitting of the tube and a visual check.

The socket terminal lugs should be soldered only with special gauges (or discarded tubes with straight pins) inserted. The vacant lugs should not be used as support points for wiring. It is strictly prohibited to use tubes which have been under overload even for a very short time due to faulty wiring or failure of circuit elements associated with the tube.

10. Semiconductor Devices (Transistors)

GENERAL

In the last decade semiconductor devices have come into wide use in electronics, radio engineering and automatics, since they are much smaller in physical size than vacuum tubes. Thus the volume of the bantam series tubes is 15 to 20 cm^3, of the microminiature series tubes, 3 to 5 cm^3, and that of semiconductor triodes type П5, only 0.5 cm^3.

In transistorization the reduction in apparatus volume is the greater, the less the volume of parts per one tube. This reduction is more marked in equipment using a large number of standard stages (computers and other devices of the commutator type).

In addition to small weight and dimensions, semiconductor devices also have a number of other advantages over vacuum tubes: negligible power consumption and voltage

requirements (from fractions of the volt to several volts); high reliability and long service life: insensitivity to mechanical effects, in particular, to acoustic vibrations; great mechanical rigidity, etc.

These features have stipulated extensive use of transistors and semiconductor diodes in radio equipment instead of vacuum tubes. *In designing transistorized radio units use is made of components which provide normal operation at reduced (as compared to vacuum tubes) voltages and power dissipation in individual elements.*

However, present-day transistors have a number of drawbacks: dependence of parameters on temperature and frequency: low input resistance of transistorized amplifiers; relatively low power output (especially at high frequencies); comparatively high noise level which limits sensitivity of amplifiers, etc.

Research during the last years has shown that many of these defects can be eliminated. Recent high-frequency (drift) transistors can operate at frequencies of the order of hundreds of megacycles per sec. The input resistance of some transistor types is as large as that of vacuum tubes (transistors controlled by a magnetic field—technetrons). High-power transistors with outputs up to 100 W have been developed, as well as low-noise transistors, the noise level of which is similar to that of vacuum tubes. New circuits reducing the temperature effects have been developed.

The industry produces hundreds of types of semiconductor devices which differ in design and characteristics. Semiconductor devices hold a firm place in various radio and electronic equipment gradually supplanting vacuum tubes. The use of semiconductor devices stipulates new apparatus designs featuring printed and integrated circuits, etc.

At present there are many types of low-frequency transistors, high-frequency junction germanium transistors used as mixers, heterodynes, intermediate-frequency amplifiers and high-rate switching. Other transistors are produced to suit specific requirements (e. g. commutation).

Also available are temperature-stabilized transistors which ensure a pulse rise and pulse decay time of the order of 0.3 μsec with a commutation time of 0.5 μsec; miniature

point-contact germanium transistors used in TV sets as video detectors and in high-speed computers.

Junction silicon diodes feature ideal rectification characteristics at relatively high temperatures (up to 165° C); they can operate at a current up to 1.5 A without artificial cooling; they feature also negligible reverse current, even at very high temperatures, and insignificant voltage drop under full load; these devices are hermetically sealed.

TYPES AND CLASSIFICATION

Semiconductor devices have a so-called *pn* (electron-hole) *junction* which represents a joint of two semiconductors with different types of conductivity (electron conductivity—*n* and hole conductivity—*p*). A barrier or depletion layer is formed at the semiconductor junction.

The semiconductor device comprising one *pn* junction and intended for rectification of alternating current is called a rectifying diode. A transistor is a semiconductor device comprising two *pn* junctions and capable of amplifying or generating electric oscillations.

The choice of transistor type is determined by the radio-electronic circuit requirements and operating conditions. Germanium transistors are commonly used at temperatures up to 80°C, silicon transistors—up to 120°C. The latter, though more effective at high temperatures, are characterized by a sharp reduction in amplification factor at low temperatures (from —20 to —60°C) and at low currents.

Junction transistors represent a system of two closely spaced *pn* junctions in one monocrystal of semiconducting material and are most commonly used.

At present, semiconductor diodes and transistors are classified by the production technique and application. Depending on the method of production there are *alloyed-junction*, *diffused-junction*, *rate-grown-junction*, and *conversion* types.

Alloyed-junction transistors are employed in r.f. switching circuits, triggers, direct-coupling multivibrators, in all low-frequency circuits (up to 10-20 megacycles per sec) over a wide power and current range.

Diffused-junction transistors are used in high-frequency ned circuits and aperiodic amplifiers, low-voltage highte pulse generators and switches.

[illegible]

cillators.

Conversion transistors are used in oscillators and amplirs of medium-power and frequency radio transmitters, comparatively high-current and low-voltage switches ith medium rates.

As to application, transistors are classified depending the permissible dissipation power on the collector, it-off frequency and current amplification factor.

The basic part of a transistor is the semiconductor ystal with a layer or layers of different conductivity ypes. Each layer of the semiconductor is provided with lead. Thus an element with three leads (called emitter, ollector and base) is obtained. The element is enclosed a case consisting of the body (base) and the cap. Depending n the application either the collector or base is attached the body.

APPLICATION AND WIRING

The relationship between parameters of a transistor nd temperature, time, operating conditions, frequency, nd the dispersion of parameters unavoidable in the process f production governs the specific requirements which the ransistorized circuit must meet. In checking and tuning uch circuits the following should be considered:

In connecting the power supply care must be taken to bserve the proper polarity, as otherwise the transistors an be broken down. One of the methods to safeguard the ransistor is to include a semiconductor diode series-conected in the power supply circuit.

The bodies of mains-operated semiconductor devices nust have a reliable contact with the circuit common wire.

Measurements should be made with the use of a tube voltmeter, since the internal resistance of instruments of other types is comparable to that of the circuit under check,

and when connected, the instruments can appreciably change the current through a transistor.

It is forbidden to break, unsolder or disconnect the base circuit of an energized transistor, as this may increase the voltage across the collector and cause breakdown of the transistor.

Particular care must be observed in checking the circuit or replacing the components with the power supply connected (more safely to cut it off).

Adequate cooling of the transistor is of primary importance for its stable and reliable operation. With an overheating of the case and junction, the maximum and permissible parameters (voltage, current and power) as well as the thermal stability of the transistor will be reduced, and almost all the parameters changed; thus cooling must be the matter of special concern, particularly for high-power transistors.

The transistor fitting to a heat-sink element should provide a reliable thermal contact. Poor contact due to warping, poorly fitting surfaces, burrs, scratches and soiling in the heat-sink are inadmissible. The temperature drop may range from 1 to 40°C; under such conditions even a high-grade transistor can be damaged due to poor contact and inadequate removal of heat. The transistor is isolated from the unit chassis with the aid of washers of mica, polyvinyl chloride films, bakelite lacquer, oxidized aluminium, etc.

Transistors operate at relatively low voltages, that is why they are sensitive to various pickups and leakages. In servicing transistorized components use is made of low-voltage (up to 12 V) d.c. soldering irons with a well grounded tip.

The electrostatic charge accumulated in a human body standing on a non-conducting surface may produce an electric pulse sufficient to damage the transistor. Therefore it is advisable to "ground" oneself before working with transistorized equipment.

The soldering should be done as quickly as possible so as not to heat the internal connections and parts of the transistor. For the same purpose the leads are soldered at some distance from the transistor body. The solder melting temperature should not be in excess of 150°C. The

lead must not be bent closer to the transistor than specified. If the bent point is too close to the glass insulators the latter may be damaged, and the transistor sealing may be disrupted. The leads should be bent uniformly at a minimum radius of 0.8 mm not to damage their conductive coating.

Nipping pliers should not be used for trimming the transistor leads as they produce a mechanical shock that may damage the delicate internal connections; scissors should be
nose pliers

Transis
only. It is inadmissible to secure them by the leads, as resonance oscillations due to vibrations and jolts may disrupt the hermetic sealing of the body or break the lead. Low-power transistors are usually attached to the panel with the use of a special cement.

Sometimes, before installing, transistors are tested with the aid of an ohmmeter. This can result in a complete breakdown of the transistor, since many ohmmeters operate with much greater voltages and currents than those specified for the transistors. Before carrying out this test, check that the maximum permissible voltage and current of the transistor are not to be exceeded; then make certain that the ohmmeter to be used has a high input resistance and produces a small current.

TYPES AND DESIGNS

Let's consider the design and features of most commonly used semiconductor devices.

Rectifying ju
Д7 (Fig. 37) are
The operating fr
50 kc/s. The maximum current amplitude at transients (with a duration of 0.1 sec) is 25 A. Depending on their parameter values ДГЦ diodes are grouped into seven subtypes (ДГЦ-21 to ДГЦ-27). They are enclosed in a metal body with a glass insulator.

The electric parameters of diodes Д7 are similar to
of diodes ДГЦ and they are similarly grouped into

from Д7А to Д7Ж. They are manufactured in an all-metal welded body and are noted for high moisture resistance.

High-power rectifying junction diodes Д302 to Д305 (Fig. 38) are also designed for rectification of alternating current. They are fabricated with a metal pressurized body provided with a radiator and a glass insulator for the lead. One of the electrodes also serves as a mounting screw for fitting the device to the panel.

Rectifying junction silicon diodes Д202 to Д205 (Fig. 39) are used for rectification of alternating current at frequencies up to 50 kc/s. They are fabricated in a metal hermetically sealed body provided with a mounting screw for the heat-sink. Their working temperature range is from −60 to +125°C.

Junction silicon transistors П5А to П5Д (Fig. 40) are used for amplification of audio frequency electric oscillations. They are produced in glass hermetically sealed bodies.

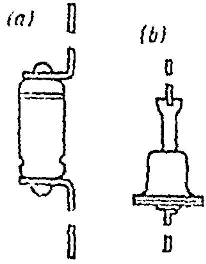


Fig. 37. Junction germanium diodes
а—types ДГЦ-21 to ДГЦ-27; б—types Д7А to Д7Ж

Germanium transistors П8 to П11 (Fig. 41*a*) are intended for amplification of high-frequency electric oscillations in push-pull circuits without a trasnformer. They are manufactured with a metal hermetically sealed container with flexible leads. The temperature range for the collector junction is between +100 and −60°C.

Silicon junction transistors П101 to П103 (Fig. 41*b*) are intended to amplify high-frequency electric oscillations. They are enclosed in a metal hermetically sealed container provided with flexible leads. Their temperature range is between −60 and +120°C.

Diffusion germanium transistors П401 to П403 (Fig. 41*c*) are intended to generate and amplify r.f. oscillation. They are made in a metal hermetically sealed container provided with flexible leads. The maximum and minimum operating temperatures of the collector junction are +80 and −60°C, respectively. High-frequency germanium transistors П12, П406, П407 (Fig. 41*d*) are intended for high-frequency amplification and oscillation.

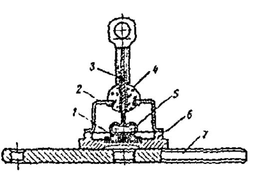


Fig. 38. High-power junction diodes Д302 to Д305

1—indium; 2—bulb (envelope), 3—tube; 4—insulator, 5—lead; 6—crystal holder, 7—heat-sink element



Fig. 39. Junction silicon diodes Д202 to Д205

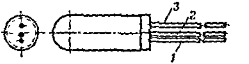


Fig. 40 Junction germanium diodes П5А to П5Д

1—emitter, 2—base, 3—collector

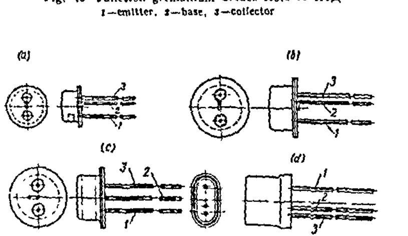


Fig. 41. Transistors

a—germanium transistors П8 to П11, b—silicon junction transistors П101 to П103, c—diffusion germanium transistors П401 to П403, d—high-frequency germanium transistors П12, П406, П407, 1—collector; 2—base; 3—emitter

CHAPTER TWO

MOUNTING

11. General

The problems of mounting radio equipment require clo e attention because of high labour requirements and the marked effects of mounting operations on the parameters of equipment.

Depending on the radio apparatus design and the scale of its production, the mounting operations constitute from 50 to 75 per cent of the total labour cost. This is due to various features peculiar to radio engineering industry, the basic of which can be summarized as follows:

1. The complexity of modern radio equipment and devices, presence of long multi-loop circuits in the unit, and a great number of inter-unit connections which call for adjusting and tuning operations and, in a number of cases, require mechanical work.

2. Complexity of operations required to ensure the desired physical parameters (resilience, permeability, resistance, etc.).

3. Considerable percentage of adjusting and finisning operations.

4. Insufficient mechanization and automation of mounting operations.

In designing radio equipment particular attention is paid to the ease of fabrication of individual components, elements and the apparatus as a whole, as it has considerable effect on labour consumption and cost.

Improvements in general design have great influence on the assembly process. Following are a few examples.

Fig. *42a* illustrates a block with 12 different parts in which holder *7* and associated elements, stop *6* and lead *10* with wire *11* are attached to block *4*. The block is provided with bush *5*, rivets *8*, auxiliary bush *12*, and cover plate *9*.

drying and long air seasoning. This design is inapplicable in flow line assembly. Construction of the unit shown in Fig. 44b makes it possible to replace the formerly used binding material with air-polymerization materials, thus considerably reducing the drying time.

operation of fastening it to the body; the use of putty however extends the process of assembly and fouls the operator's bench.

A plug connector attachment more suitable for production (Fig. 43*b*) has been designed, in which the plug connector serves as the mandrel in moulding the apparatus body,

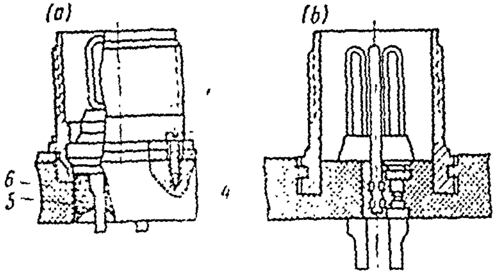


Fig. 43. Versions of plug-and-socket connector fitting
a—poorly adapted for production; *b*—well adapted for production

i.e. the body is integral with plug connector. This method eliminates preliminary assembly of the plug connector, saving time and labour; in addition, the number of parts

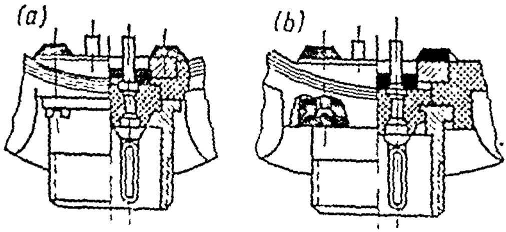


Fig. 44. Attachment of plug-and-socket connector to body
a—poorly adapted for production; *b*—well adapted for production

required is reduced, the operation of attaching the connector to the body is eliminated and the sealing of the body improved.

Another method of attaching the plug connector to the body is given in Fig. 44*a*. For better sealing, the plug connector is coated from the inside with a cement (nitrocellulose enamel with gypsum) which requires a constant-temperature

drying and long air seasoning. This design is inapplicable in flow line assembly. Construction of the unit shown in Fig. 44b makes it possible to replace the formerly used binding material with air-polymerization materials, thus considerably reducing the drying time.

Two ways of securing a glass part to a device body are illustrated in Fig. 45a and b. In the first case (Fig. 45a) the glass part inserted into body 5 is clamped with ring 1 and cemented with putty 6. This method requires a period of time for polymerization of the putty which, however, does not ensure adequate protection from dirt and moisture. More so, the application of the putty is labour-consuming.

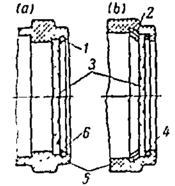


Fig. 45. Two versions of fitting a glass to the body
a—poorly adapted for production, b—well adapted for production

In the second case (Fig 45b), packing ring 4 is first fitted into the body, followed by glass 3 which is pressed with the aid of special spring 2 made in the shape of a truncated cone slit for better springing. This method obviates the cementing and polymerization of the putty, improves moisture- and dust-protection of the body.

Usually the ease of fabrication of an apparatus and its constituent elements is estimated with the aid of a certain *system of accepted criteria of fabrication which can be absolute and relative.*

Absolute criteria of fabrication are used mostly when the production of a given device has been organized for the first time and its design cannot be compared with any similar device from the point of view of its adaptability to production

Relative criteria are used when there are several similar designs which can be compared from the point of view of fabrication. These designs can be the successive modernizations of one and the same device and can also present different devices of similar design manufactured simultaneously.

12. Detachable Joints

Detachable joints enable parts to be connected or disconnected many times without deformation. Mounting with the use of threaded joints (screws, bolts, nuts, wood screws) is the most widely employed method of detachable connection of parts.

Threaded joints in radio engineering have the following distinctive features: rapid assembly, sometimes up to 10 sec, extensive use of screws and nuts of different shapes

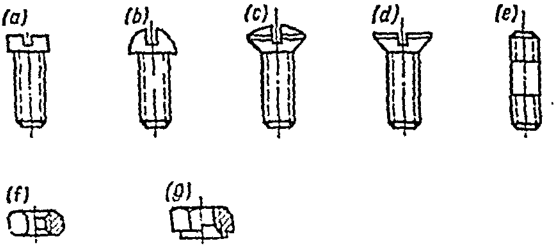


Fig. 46. Principal types of screw fasteners employed in radio engineering

a—rectangular-head screw; *b*—round-head screw; *c*—button-head screw; *d*—sunk-head screw; *e*—pin; *f*—hexagonal nut; *g*—stepped hexagonal nut

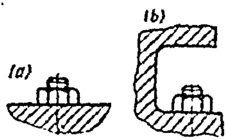


Fig. 47. Screwed connections

a—open-type, *b*—closed-type

and diameters less than 6 mm, necessity to ensure a torque value within close limits and to preserve the external finish of the parts being assembled.

The principal types of threaded joints are screws with straight and cross-shaped slots and various shapes of heads, bolts and nuts with hexagonal and round thumb heads, pins and wood screws without washers and with flat and spring washers (Fig. 46). With the aid of these parts open- and closed-type joints can be made (Fig. 47). Threaded elements may also be employed as contacts, hinges, etc.

The choice of the right tools is of primary importance in making threaded connections. Thus, the size of the screw driver should accurately match the screw size, otherwise either the required strength of the joint cannot be obtained or the screw slot will be damaged. Nuts and bolts should be tightened with captive or socket wrenches only. Pliers

or other improvised tools should not be used for this purpose.

Calibrated tools with adjustable torque are in common use for tightening screws, bolts and nuts. Torque wrenches and screw drivers ensure a required tightening force and automatically disconnect the wrench head or the screw driver blade from the handle when they are overforced. In mass production use is made of pneumatic and electrical tools (speeder wrenches or nut runners).

The variety of technological requirements calls for the use of tools of different design.

In large-scale production it is more expedient to use stationary single- and multispindle speeder wrenches since they allow both hands to be used in work. In addition, the weight of stationary tools is not so drastically limited, which allows us to make the wrenches reliable in operation and with extended service life. The choice of either single- or multispindle machine is governed both by the design of the device assembled and engineering and cost considerations.

In mounting medium- and large-size units and units in which the fasteners are fitted from several sides and in difficult-to-reach places, universal-type portable electric or pneumatic speeder wrenches are more convenient. Besides, they are much cheaper than the stationary ones.

On the work benches and conveyer lines in mass- and large-scale production use is made of electromechanical light and small-size speeder wrenches with flexible shafts. But in batch production of radio devices mounted on stands, it is recommended to use tools with flexible cords and air hoses and with built-in electric or pneumatic motors, since they are more convenient.

When choosing the type of drive, one should remember that for mounting work-on stands in large-scale production it is better to use pneumatic-drive tools, since these are more reliable in operation and lighter; in small-scale production speeder wrenches with electric drive not requiring compressors are preferable.

Straight and angular speeder wrenches are used, as the case may be. The tools can be mounted and fixed on the working station by different methods

Connection of threaded parts with the use of gadgets is employed when it is necessary to mechanize auxiliary operations: to locate the screw in a definite position, to assemble the screw and washer, to feed the fastener under the speeder wrench tip. With driving screws and bolts or nuts, the tip should easily fit the tool spindle and transmit the necessary torque to the screw, bolt or nut. The types of tips and their seats are presented in Fig. 48.

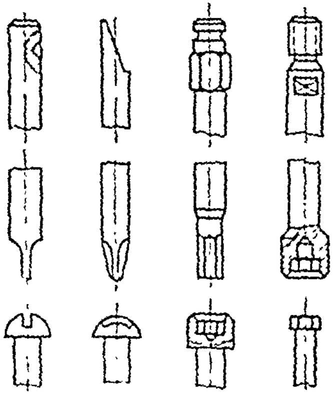


Fig. 48. Types of tips

In batch production for tightening fasteners of M1.7 to M4 thread diameter the electromechanical speeder wrench shown in Fig. 49 is used. Serving as the drive is a commutator motor *2* with built-in reduction gear *3* and holder *7* attached to shaft *5* of the reduction gear by means of pin *6*.

The replaceable tips are secured to the holder with the aid of spring *8*. The fasteners can also be tightened by hand

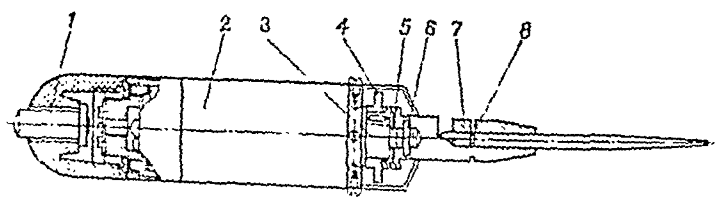


Fig. 49. Electromechanical speeder wrench

(to increase the torque). For this purpose ratched disk *4* is fitted on the cover of reduction gear *3*; this disk engages the holder pawl and, on turning the electric motor housing, it transmits motion to the tip. In operation the speeder wrench is not fixed in position, and is switched on by depressing push-button *1*.

neumatic speeder wrenches (Fig. 50) are frequently oyed for assembly operations on stands and benches atch production. The wrench is turned on by a cock y a foot-operated valve. Compressed air rotates four-le pneumatic motor *13* whose rotor *12* turns in ball rings *14* and *11*. The motion to spindle *3* fitted in housing and turning in ball bearing *4* is transmitted through

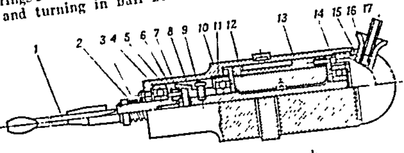


Fig. 50 Pneumatic speeder wrench

a friction clutch (disks *8* and *6*). Friction disk *8* is secured to the rotor shaft by means of screw *9*; disk *6* is attached to the spindle by means of pin *5* and screw *7*. The changeable tips *1* are installed in the spindle cylindrical hole and fastened by a locking lug with a flat surface

The tightening torque is dependent on the pressure exerted on screw or nut being tightened For screwing the fasteners home by hand there is spring *2* which acts as a back-running clutch. Flexible hose *17* (rubber tube 4 6 or 6 × 8 mm) is introduced into connecting branch *16* following which bush *15* is inserted into the hose end and the connecting branch is screwed into the housing threaded hole. This attachment is handy and reliable in operation.

When assembling screw joints, only final tightening of the joint is done using the tool; all other operations ar done by hand. Large-size threads should be lubricated wit oil or grease beforehand.

In assembling multiscrew joints (e.g. fastening uni to the chassis with the aid of a large number of screws a nuts) a definite sequence of operations should be observ

Connection of threaded parts with the use of gadgets is employed when it is necessary to mechanize auxiliary operations: to locate the screw in a definite position, to assemble the screw and washer, to feed the fastener under the speeder wrench tip. With driving screws and bolts or nuts, the tip should easily fit the tool spindle and transmit the necessary torque to the screw, bolt or nut. The types of tips and their seats are presented in Fig. 48.

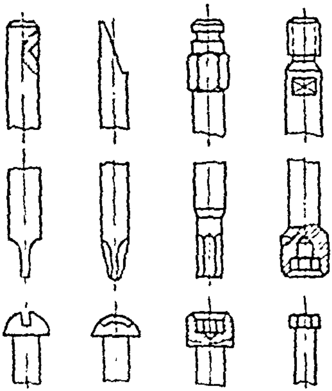


Fig. 48 Types of tips

In batch production for tightening fasteners of M1.7 to M4 thread diameter the electromechanical speeder wrench shown in Fig. 49 is used. Serving as the drive is a commutator motor *2* with built-in reduction gear *3* and holder *7* attached to shaft *5* of the reduction gear by means of pin *6*.

The replaceable tips are secured to the holder with the aid of spring *8*. The fasteners can also be tightened by hand

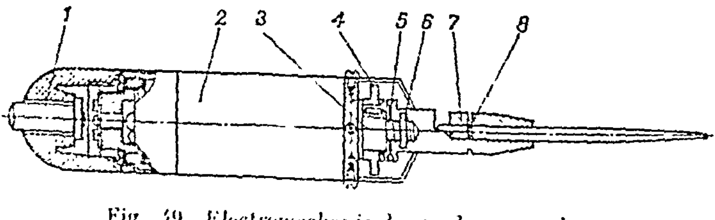


Fig. 49. Electromechanical speeder wrench

(to increase the torque). For this purpose ratched disk *4* is fitted on the cover of reduction gear *3*; this disk engages the holder pawl and, on turning the electric motor housing, it transmits motion to the tip. In operation the speeder wrench is not fixed in position, and is switched on by depressing push-button *1*.

Pneumatic speeder wrenches (Fig. 50) are frequently employed for assembly operations on stands and benches in batch production. The wrench is turned on by a cock or by a foot-operated valve. Compressed air rotates four-blade pneumatic motor *13* whose rotor *12* turns in ball bearings *14* and *11*. The motion to spindle *3* fitted in housing *10* and turning in ball bearing *4* is transmitted through

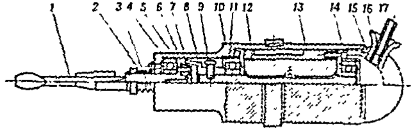


Fig. 50 Pneumatic speeder wrench

a friction clutch (disks *8* and *6*). Friction disk *8* is secured to the rotor shaft by means of screw *9*; disk *6* is attached to the spindle by means of pin *5* and screw *7*. The changeable tips *1* are installed in the spindle cylindrical hole and fastened by a locking lug with a flat surface.

The tightening torque is dependent on the pressure exerted on screw or nut being tightened. For screwing the fasteners home by hand there is spring *2* which acts as a back-running clutch. Flexible hose *17* (rubber tube 4 × 6 or 6 × 8 mm) is introduced into connecting branch *16* following which bush *15* is inserted into the hose end and the connecting branch is screwed into the housing threaded hole. This attachment is handy and reliable in operation.

When assembling screw joints, only final tightening of the joint is done using the tool; all other operations are done by hand. Large-size threads should be lubricated with oil or grease beforehand.

In assembling multiscrew joints (e.g. fastening units to the chassis with the aid of a large number of screws and nuts) a definite sequence of operations should be observed

so as to avoid warping and deformation of the unit. Usually, the operation is performed step by step, working from the centre to the edges of the unit.

During operation of the equipment the screw joints can loosen up due to shaking and vibration, and individual screws and nuts can even completely turn off. This is avoided by locking the joints.

The inadvertent unscrewing can be prevented by two methods: by creating sufficiently large friction between the connected elements of the structure or by the application of special auxiliary parts.

Required friction between the screwed surfaces can be obtained without additional parts. Sometimes unscrewing is prevented by the use of paint or varnish if the joint is not to be dismantled frequently. This method gives good results for small-size screws (from 3 to 6 mm in diameter). Best results are achieved if enamels are employed.

The measures against accidental unscrewing using special additional elements are resorted to in cases when the joint is to be dismantled often enough, as required by production or operating conditions. This method is also used for rarely dismantled joints employing large-size screws or bolts (more than 4-6 mm in diameter).

There are many various designs of locking devices. The simple one comes in the form of a lock nut on the screw or bolt above the basic nut tightened up so that it is in good contact with the latter. A disadvantage of this method is that the joint becomes heavier due to longer bolts and additional nuts, and the joints are not quite reliable under heavy vibration.

In case of a multibolt joint the inadvertent unscrewing can be dealt with by passing a lock wire through special holes in the bolt heads. The wire is stretched in such a manner that after twisting its ends it should facilitate the tightening of the bolts or screws. Another method of locking screw joints is with the aid of cotter-pins.

Far more extensively employed in the mounting of radio equipment are split spring washers and "star"-type washers which due to their resilience provide the tightness of the joint, preventing unintentional loosening of the fasteners.

13. Permanent Mechanical Joints

Making permanent joints of elements is one of the most common operations in the assembly of radio equipment. Permanent joints are those which cannot be dismantled without considerable destruction of the connected parts or materials.

These joints are made with the use of solid or hollow rivets (pistons) by soldering and brazing, by using plastic deformation of the metal of individual elements or parts. Also by welding, pressing, puttying and cementing (for sealing with the use of thermoplastic and thermosetting materials), by filling, sewing, caking, etc. Of these mainly used in the assembly of radio equipment are riveting, flanging out, soldering, welding and cementing.

In this section we shall deal with mechanical joints of parts in assembly, viz. riveting and flanging out; the other methods will be considered in the following sections of this chapter.

RIVETING AND FLANGING OUT

In riveting (or flanging out) the connected parts are tightly pressed together. The resulting friction prevents mutual displacement. The rivet or pin on one of the parts is driven in and the material fills the hole provided for the rivet or pin.

Fig. 51 illustrates the process of making a permanent mechanical joint by directly flanging out a pin. The same process referred to rivets is illustrated in Fig. 52. The portion of the pin or rivet to be flanged or driven is shown in Figs. 51 and 52 by broken lines.

Non-metallic parts are generally connected with the use of tubular and semihollow rivets (Fig. 53). The hole for the rivet should be larger than the rivet shank diameter. When connecting insulating materials (such as ebonite, textolite, hardened paper) the holes are made slightly larger than those in metal parts.

Various types of rivets are used in radio engineering; the most common of them are illustrated in Fig. 54.

For a high-quality riveted joint it is important to choose a rivet with a shank length sufficient to obtain a driven head of proper shape and thickness.

The driven or closing head of the rivet can be of different shapes. The clearance between the shank and the material can also be different, depending on the joint in question, and the rivet itself can be made of different materials with

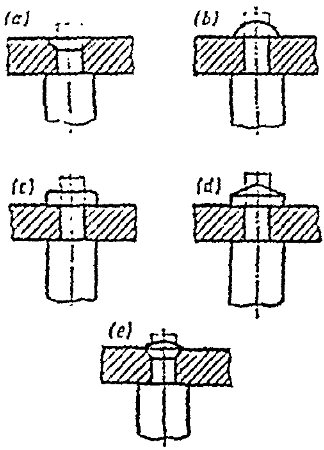


Fig. 51. Flanging out connecting pins

a—forming a countersunk head; b—button head; c—flat head; d—cone head; e—round-top countersunk head

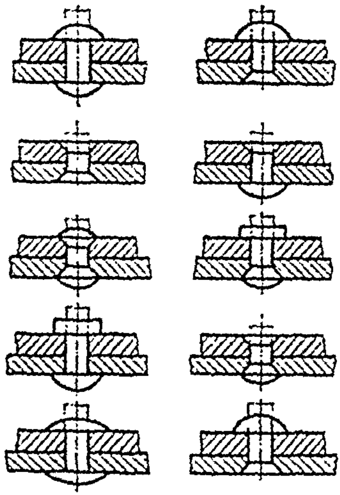


Fig. 52. Riveted joints

amount of deformation varying with a shank length and method of riveting. Therefore the required length of the rivet shank is selected experimentally. For approximate calculations of the shank length the following formula can be advantageously used

$$l = s + 1.5d$$

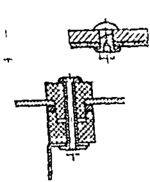
where d—shank diameter in mm;

s—total thickness of sheets or plates to be riveted.

Riveting can be performed by two methods. With the first method, the riveting tool strikes the set or manufac-

·ed head while the driven head is formed by the shank ing pressed against a hold-on. With the other method, tool strikes the end of the projecting shank until the iven head is formed, the manufactured head being held the hold-on.

The pin or rivet shank is inserted into the hole with e aid of a support. Supports are frequently made with



ɡ. 53 Riveting with tubular and semihollow rivets

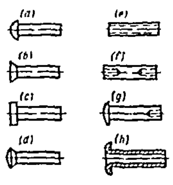


Fig. 54. Types of rivets
a—button head, *b*—countersunk head, *c*—flat head, *d*—round head, *e*—tubular; *f*—rod rivet, *g*—special-type, *h*—piston-type rivet

ovable jaws *1* which grip part *2* (Fig. 55) protecting it ainst bending and flattening in the process of riveting. nall-diameter rivets are fitted into the hole with the aid tweezers or pliers. To protect the rivet head from damage, e plier jaws are annealed or provided with inserts of fter metal (brass, copper).

In case of misalignment of the holes in the parts to be ld together or if the punched holes are not smooth enough ey are calibrated by reamers without increasing the ameter. "Catchers" (locking pins) in the shape of rods ound at one end to fit the holes are used to prevent mutual splacement of parts that are to be joined together by veral rivets.

The catchers are inserted into the holes which are remote om each other and are arrested by their shoulders against ne of the surfaces of the part to be riveted. After that the

rivets are fitted in. If the rivets are numerous, they are first fitted into every other, third or fifth hole, inserting the remaining rivets after these have been slightly riveted.

The parts to be riveted and the rivets themselves are generally made of steel grades 10 or 20, stainless steel, brass, copper, aluminium, duralumin. Duralumin rivets are tempered beforehand. Hollow rivets and parts are often flanged out on drilling machines (Fig. 56) and sometimes on lathes. This method of flanging out is extensively employed for large-size parts.

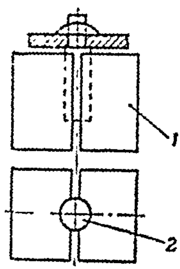


Fig. 55. Support used in riveting connecting pins

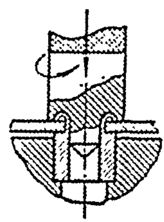


Fig. 56. Flanging out tubular rivets on a drilling machine

High-quality rivet joints can be obtained if the peculiarities of the riveting process are taken into consideration.

In connecting metallic elements of a structure, possible fluctuations of the hammering force will have little bearing on the quality of the joint. However, if non-metallic and particularly low-elastic elements are joined, the fluctuation of applied force during riveting is of great importance and it can be the cause of defects and even destruction of the elements. If it becomes evident that uniform force cannot be ensured flanging out should be used.

Sometimes the edges of the flanged-out rivets are additionally caulked. This method provides a good connection of the parts, however it is accompanied by considerable strains in the joint which prevent the use of this method for connection of brittle elements (ceramic, thermosetting plastics or hardened paper).

RIVETING EQUIPMENT

Permanent joints in radio equipment are also made with the aid of mechanical, hydraulic, pneumatic and electromagnetic presses. Let us consider those most widely used.

Mechanical presses are frequently employed. A functional *diagram* of a pendulum-type foot-operated press is presented in Fig. 57. During operation lever *1* turns about axis *2*

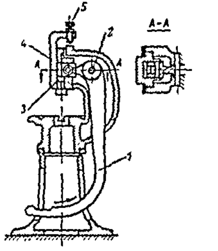


Fig. 57. Foot-operated pendulum press

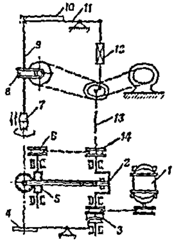


Fig. 58. Diagram of high-speed riveting machine

in the direction shown by the arrow. Connected to the lever, link *3* moves slide *4* down to the work located on the table. The stroke of the slide is adjusted by screw *5* as required. This press is very convenient, as the hands of the operator are free, and he can align and hold the parts when required.

Riveting, caulking and flanging operations in radio engineering are carried out with the use of specialized mechanical riveting machines. Figure 58 illustrates a functional diagram of a high-speed riveting machine designed for producing permanent joints with small-size rivets; it can also be used advantageously for flanging out bushes and for other operations.

The machine is powered by electric motor *1* through a belt transmission imparting rotation to crankshaft *2* by means of friction clutch *3* turned on and off by foot pedal *4*. The crankshaft is linked to draw rod *13* provided with shock absorber *12*. During shaft rotation the draw rod imparts vibratory motion to beam *11* (with wooden bar *10*) about

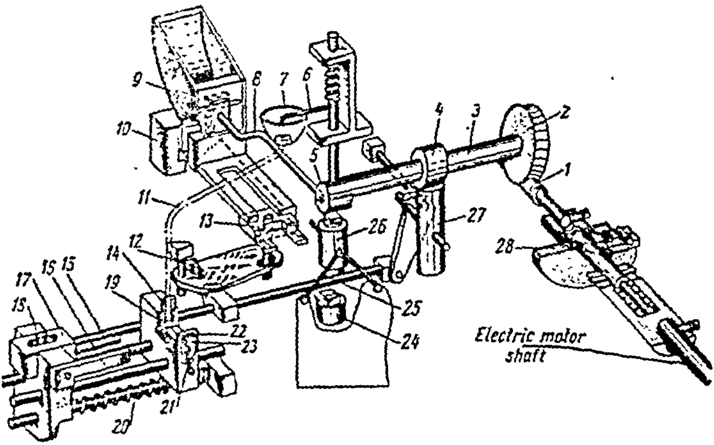


Fig. 59. Functional diagram of automatic machine for pressing pins into sockets

the beam fulcrum. The wooden bar serves to reduce noise from shocks against spindle *9* which is attached by a leather strip to bar *10*.

Spindle *9* is provided with a key and freely passes through the hole in worm wheel *8* rotated from worm *5* which in its turn receives rotation via a belt transmission from pulleys *6* and *14*. Driving pulley *14* turns jointly with crankshaft *2*. The machine kinematics ensures a reciprocating and rotary motion for spindle *9* and hence to set die *7* (or flanging-out device) secured on the spindle taper. These operations of the tool provide good shaping of the rivet heads and proper flanging out combined with high efficiency of work.

Pressing operations are performed with the use of automatic and semiautomatic high-efficiency machines. Figure 59

represents the pictorial of an automatic machine intended for pressing rods into the plug connector tubes. The machine together with an electric motor is mounted on a 200 × × 500 mm panel. The automatic machine is driven by worm *1* and wheel *2* from an electric motor rated at 0.25 kW, 1,350 rpm. The worm is turned via clutch *28* which automatically disconnects the electric motor, if the parts fed to the machine are not of standard dimensions.

Cam gears *12* and *27*, upper die *26* and rotary shaft *22* with cams *23* are operated from worm wheel *2* fitted on shaft *3* provided with eccentrics *4* and *5*.

The automatic machine operates in the following manner. Contact tubes duly selected and put into feeder *9* are ejected by means of lever *8* and cam gear *12* through a slot into receiver *10*. From the receiver the tubes one by one pass into the slot of slide *13* and subsequently cam *12* feeds them onto lower die *24*. Receiver *10* also serves as an interrupter.

Rods to be pressed in are supplied to feed bin *7*. When lever *6* vibrates, they pass by way of tube *11* into receiver *14* whence they are fed to recess *19* of rotary shaft *22* with cams *23*. Shaft *22* is turned (to position the rod horizontally) by means of pusher *16* and cam gear *27*. The rod is further moved by needle *15* from the shaft recess into the contact bush at a depth adjusted by movable needle holder *17* in the slot of slide *18* driven by cam gear *27*.

On completing the above operations, slide *13*, actuated by spring *20*, rotary shaft *22* and spring *21*, returns to the initial position. At the same time upper die *26*, driven by eccentric *5*, forces the rod into the bush Spring *25* returns the upper die into the original position.

Hydraulic presses for fabricating permanent joints are generally used in the process of preliminary assembly. They are powered from a built-in motor and, in certain designs, from a general-purpose hydraulic mains.

A simple hydraulic press is presented in Fig. 60. It comprises electric motor *1* which drives the pump. The latter forces oil through a slide valve, operated by handle *2*, into working cylinder *3* fitted with pressure gauge *4*. The oil under pressure forces the piston with slide *5*, carrying the working tool, to move to or fro.

Pneumatic presses used for assembly are generally operated by compressed air from the shop air mains and, in rare cases, by a special unit. Compressed air, passing

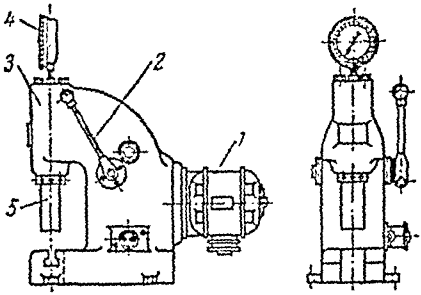


Fig. 60. Pictorial diagram of a small-size hydraulic press

through the valve, is supplied to the air distributing device whence it is directed into the cylinder and moves the piston. Pneumatic presses feature percussion-type operation due

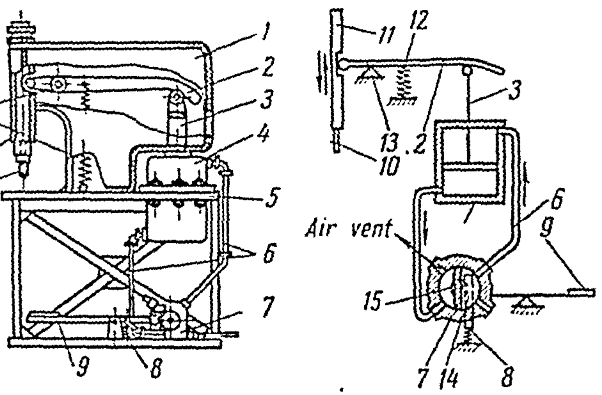


Fig. 61. Functional diagram of lever-type pneumatic press

to kinetic energy accumulated at the end of the working stroke of the piston and connecting rod carrying the tool at its end.

The press design illustrated in Fig. 61 is intended for flanging out hollow rivets and riveting. It consists of body *1*

installed on base *5*, air cylinder *4* (100 mm in diameter) with connecting rod *3*. The connecting rod rests against lever *2* hinged on axle *13* and tensioned by spring *12*. The short arm of lever *2* is hinge-connected to spindle *11* carrying punch *10*. The spindle is given a translatory motion via lever *2*, connecting rod *3*, operated by pneumatic system *6* and starting cock *7*, controlled with the aid of pedal *9*.

The starting cock has four branchings, three of which are connected to pipe lines and the fourth is used to discharge waste air. Gear wheel *15* mounted on the axle at the lug of the starting cock body serves to switch over the air flow in the cock. The wheel is turned from rack *14* which is moved by the pedal and is returned to the initial position by spring *8*. The force exerted by the machine is up to 1.6 tons, with the compressed air pressure in the line of 3 to 5 atm.

Electromagnetic presses employ electric magnets fed by d.c. or a.c. If powered by a.c., they are supplied directly from the power mains, d.c. presses require intermediate rectifiers which convert a.c. into d.c. Electric magnets designed for a.c. operation are less economical and more complicated than d.c. magnets, due to which the latter are more extensively used.

The electric magnets differ in design depending on the application. Usually the procedure of designing a d.c. magnet for the presses with a given force F (in kg) and gap δ (in mm), defining the connecting rod stroke, amounts to determining the number of ampere-turns and the coil winding data.

Electromagnetic presses based on the use of solenoids and electric magnets are now widely employed in radio engineering for riveting, flanging out and other operations associated with the production of permanent joints. In these machines the prime mover and the tool are combined in one unit which allows to gain space and convenience of operation.

An electromagnetic press of this type is shown in Fig. 62. It consists of a cast or welded body with base *1* and mounted on it coil *2* of the solenoid, and core *3* within the coil. The solenoid is hinge-connected by draw rod *4* to beam *5* rigidly fitted on axle *9*. On the other end of the beam a counter-

weight is fitted which lifts the solenoid core with the draw rod (when the solenoid coil is deenergized) until it rests against stop *6*. In some designs springs are used instead of the counterweight. The springs are operated either by compression or tension depending on their position respective to the beam fulcrum.

Yoke *7* is fitted to the other end of axle *9* which goes through the press body. Draw rod *10* hinged to slide *11* is fastened to a pin in the yoke slots. The required tool is attached to the lower end of the slide.

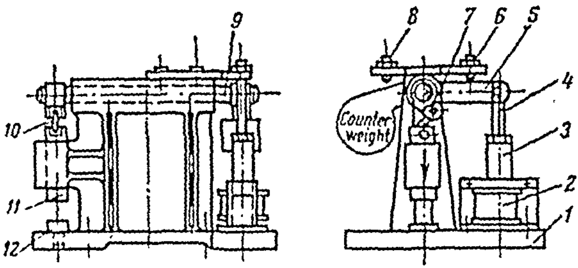


Fig. 62. Functional diagram of electromagnetic solenoid press

The parts to be assembled or stamped are respectively placed in the appropriate assembly contrivance, or lower die *12* located on base *1* and aligned with the slide. The slide stroke can be adjusted vertically by means of stop *8*.

The press is controlled by a foot pedal which switches on coil *2* of the solenoid after which the coil retracts core *3*. This action forces down slide *11* with an appropriate tool at its end (through draw rod *4*, beam *5*, axle *9* with yoke *7*, and draw rod *10*). On releasing the foot pedal, the solenoid coil is deenergized and the counterweight (or spring in other designs) will return the system to the initial position.

14. Soldering Wire Connections

GENERAL

Soldering is intended to obtain a permanent joint of metallic parts with the aid of a molten metal or alloy (solder) which, on cooling, forms a seam, holding the parts. In the

process of soldering a mutual dissolution and diffusion of the solder and the metal of mounted parts take place which provide mechanical strength, tightness, electric and thermal conductivity of the soldered joint.

The soldering temperature is below the temperature of melting of the parts connected (in contrast to welding). The temperature of the solder should be somewhat higher than its melting point. This is necessary for complete filling of the gap between parts and for good wetting of the surfaces.

The process of formation of soldered joints can be divided into the following stages:

heating the basic metal to a temperature near to the solder melting point;

melting the solder;

spreading liquid solder over the hard metal surface and filling the gap between the parts;

partial dissolution of the basic metal in the liquid solder and mutual diffusion of metal;

cooling and crystallization of the solder.

In practice, the listed above stages overlap each other and are also accompanied by certain auxiliary processes.

Soldering is performed with the aid of fluxes which protect the surfaces to be joined against possible oxidation at elevated temperatures. Fluxes not only form a liquid or gaseous protective medium but also additionally clean the surface of the parts from dirt, dissolve oxide films and promote better flowing of the solder into the gaps between the parts.

Various non-ferrous metals and their alloys are used as solders (hard or soft). Soldering with the use of hard solders is known as brazing.

Hard solders or brazers (copper, copper-zink, silver) have high melting points (700 to 900°C) and can ensure sufficient mechanical (tensile) strength of a joint (up to 50 kg/mm^2).

The melting point of soft solders is below 350°C, their mechanical strength is relatively low (tensile strength is from 5 to 7 kg/mm^2). Usually tin-lead, bismuth, cadmium and other alloys are employed as soft solders.

Both types of solders are extensively used in radio engineering; wiring connections, however, are made with soft solders only.

SOLDERS AND FLUXES

Hook-up wires are joined with the aid of tin-lead solders ПОС-40 and ПОС-61 and tin-cadmium solder ПОК-56. Solder ПОС-61 is used for tinning current-conducting cable cores, cable terminals, contact lugs, and for soldering joints which can be heated to 250°C. Solder ПОС-61 is used for joining and tinning parts heated not above 200°C, and solder ПОК-56 for tinning and joining parts that can be heated up to 140°C.

Solders may be either in the form of a tube filled with colophony (rosin-core) or as rods or wire of 3 to 4 mm in diameter. Rosin-core solder is preferable; it is made in the form of a round-section tube of small diameter filled with colophony flux. The main advantage of such solders is that the application of solder and flux to the joint takes place simultaneously.

Rosin-core solders improve the quality of a joint, appreciably save time in mounting operations, and are convenient in work. In addition, this considerably reduces expenditure of solder and flux. An important feature of rosin-core solders is that only required amount of flux is supplied to the joint and that the solder melts when the flux is already heated to an active state. The amount of flux in the core varies with the type of solder.

The use of rosin-core solders rules out the possibility of incidental fouling of the flux as it might happen with rod or wire solders when flux is applied separately.

In the simplest design rosin-core solder is made in the shape of a tin-lead alloy tube filled with flux (Fig. 63*a*). This construction has certain disadvantages, as flux supply can be interrupted, if there are hollows in the flux core; also the flux can flow out and evaporate before the solder is melted in which case no good quality of joint can be expected.

The possibility of formation of hollows in a rosin-core solder and of interruptions in the flux supply may be reduced

re intricate form of the flux core is adopted. Rosin-
lders with shaped flux cores are illustrated in Fig. 63b;
cores with three and five flux sticks are shown in
63c.
uxes should meet the following requirements:
Melting point of a flux should be below that of the
r.
. The melted flux should readily and evenly spread
the basic metal, easily penetrate the joint; but it

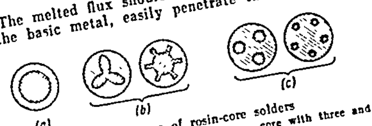


Fig. 63. Types of rosin-core solders
a—round rosin (flux) core, b—shaped core; c—core with three and five flux sticks

should not be too viscous and should not "run" away from the joint area.

3. The flux should easily and completely dissolve the oxides of the basic metal; this process should be completed by the time the melted solder is applied to the joint.

4. The dissolving of the oxides should not take place too early; if otherwise, the flux will act before required. Thus the flux action should occur at a temperature several degrees below the solder melting point.

5. The flux should not form compounds with the basic metal or be absorbed by the latter, otherwise the mechanical strength and corrosion resistance of the joint will be affected.

6. The flux should uniformly cover the surface of the basic metal near the joint, protecting it against oxidation during soldering. It is essential however that the adhesion o the flux to the basic metal be weaker than that of the solde

7. The remainder of the flux and the products of i disintegration should appear on the solder surface as so as it adheres to the basic metal.

8. The flux and the products of its disintegration shou be easily removed from the basic metal and the joint a soldering.

9. Neither the flux nor the products of its disintegration should emit harmful gases.

As it is usually impossible to wash soldered joints to remove the flux remainder completely, the fluxes used should meet additional requirements.

The flux should not leave remains capable of corroding the soldered parts, and the evaporations emitted during soldering should be harmless for the surrounding parts if accumulated on their surfaces. The flux remains should be highly resistive to electric current (be a good insulator); the flux should also be hard and smooth so as not to accumulate dirt and dust causing leakage of current. The flux remains should not be hygroscopic, otherwise in case of excessive humidity, it will absorb moisture producing electrolite on the surface of the joint and resulting in current leakage and corrosion.

Colophony is the best to meet these requirements; this explains the wide use of this material as a flux for soldering interconnections in radio devices.

In wiring operations liquid rosin (colophony) and compound ЛТИ-120 are generally used as fluxes. Liquid rosin (30% solution of rosin in ethyl spirits) is used for soldering in most wiring operations; flux ЛТИ-120 is used in soldering on nickel- or zink-plated steel tags, in soldering wires of resistive alloys (constantan, nichrome, and others). In soldering printed circuits with a hard-cardboard base flux ЛТИ-115 is used as it does not impair insulating property of the hard cardboard.

SOLDERING METHODS

To clean scale off the soldering iron tip the heated iron is dipped into a lump of colophony or wiped with a coarse cloth. When fouled and darkened the lump of colophony is replaced with a fresh one. Pits on the tip surface are removed by filing. Following that, the soldering iron is wetted on all sides in colophony and dipped into the solder.

The temperature of heating of the soldering iron depends on the solder grade (Table 4).

The soldering temperature is controlled by varying the voltage applied to the tool. Under normal operating condi-

Table 4

Characteristics of Solders Grade ПОС and ПОК

Solder grade	Temperature, °C	
	solder melting point	soldering iron
ПОС-40	235	250-260
ПОС-61	190	200-210
ПОК-56	124	140-150

tions the solder should melt quickly but not roll down from the tip end; colophony does not burn instantaneously but remains on the tip in the form of boiling beads. Care must be taken not to overheat the soldering iron.

A thin coat of flux is applied to the joint with the aid of a soft brush.

To avoid defective (cold) soldering joints, the joint area should be heated to the solder melting point by pressing the flat side of the iron (but not the edge of the tip) to the joint so as to ensure a maximum heating area.

In certain cases heat removal (heat-sink) is required. Soldering with heat-sink (ensured by means of forceps provided with copper caps at the ends) is performed if the distance from the point of soldering to the radio component body is less than 8 mm (Fig. 64*a*), when soldering bare wires or leads enclosed in polyvinylchloride tubes (Fig. 64*b*), and also in soldering lugs of glass leads in sealed components (Fig. 64*c*).

In soldering, rosin-core solder is held in the left hand and, with the soldering iron in the right hand, is applied to the joint area simultaneously with the iron tip.

When rod solder is used, the method of soldering is similar to the described above differing in that the flux is first applied to the joint area. If the left hand is to be free during soldering (for instance, when using a heat-sink), molten solder is transferred to the joint area on the soldering iron tip, preliminarily cleaned in a lump of colophony (solder after melting remains on the tip end in the form of a small run).

During soldering care should be taken not to touch the adjoining components and wires with the heated portion of the soldering iron. In wiring in tight places heat screens are employed. In the process of soldering the apparatus must be protected from drops (splashes) of solder and flux. Drops of solder must be immediately removed with tweezers. When soldering ends of flexible wires to "floating" lugs the latter must not be "flooded" with solder. When soldering cable terminals check that the solder cements the wire

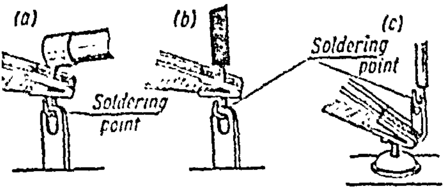


Fig. 64. Soldering with the use of heat-sink

a—with a spacing between soldering point and body; b—soldering of wires or leads enclosed in tubes; c—soldering of hermetically sealed components

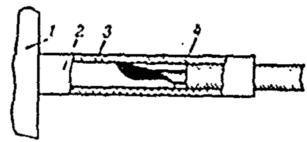


Fig. 65. Soldering of a wire to contact of plug-and-socket connector

current-carrying core to the inner and end face surfaces of the terminal lugs and also covers the butt end of the core and slot between the lugs.

The procedure of wiring plug connectors is as follows (Fig. 65). Fit on the soldered wire a polyvinylchloride (pvc) tube *2* (15 to 20 mm in length) of an internal diameter equal to the diameter of contact *3* of the plug connector. Insert cleaned end of wire core *4* into the hole of the plug connector contact and solder it. After washing the assembly and checking the quality of soldering, fit the pvc tube onto the contact and soldered joint until it rests against plug *1* of the connector.

If several wires of more than 3 mm^2 total cross section are soldered to a plug connector, special transitory contacts should be employed. In this case a longer pvc tube should be taken. The wires are soldered in a clockwise direction starting from the lower row of plug connector contacts. If the wires (bunched conductors) are soldered to the contacts

before the plug connector is fitted to a unit, the connector *should be clamped in a vice (Fig. 66)*. The use of the vice *1* allows us to fix a component or unit *2* in a required position and thus to free the left hand. The plug connector is protected with a felt pad *3*.

The ends of the shielding braids of several wires are soldered as shown in Fig. 67. Sometimes the ends of shielding braids *1* are fitted and soldered into one cable terminal

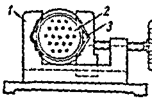


Fig. 66. Fastening of plug-and-socket connector in a vice

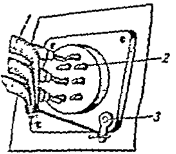


Fig. 67. Soldering shielding braid of wires to body lug

which is clamped under the fastening screw of a plug connector instead of connecting to body tag *3*. The conductors are soldered to contacts *2*.

The conductors and shielding braids of r.f. cables type PK are soldered to the contacts of coaxial connectors in many ways, depending on the type of connector and method of cable-end sealing. In the process of soldering particular care must be taken not to damage the internal polyethylene insulation. Low-temperature solder ПОК-56 is used. If a spacer (pressboard or linoxyn tube) is placed between the shielding braid and insulation, solder ПОС-40 can be used.

To remove flux remains, the joint area should be washed immediately after soldering (before the metal cools down) with a calico tampon wetted in spirits and wound on tweezers. The use of other solvents for cleaning is not recommended as they may damage the varnish coating and the marking inscriptions.

After soldering, the apparatus and wiring should be blown out with compressed air to remove dust and wire

leftovers; gun-type nozzles are recommended. The completely finished and cleaned wiring is carefully located (arranged) as required on the chassis by means of forceps with pvc tubes fitted on the forceps ends. Great care must be exercised in arranging the wiring so as not to break or cut the current-conducting cores of the wires and the leads of the hook-up radio elements and not to short-circuit the bare wires.

The wires should not obstruct reading of marking inscriptions and uninsulated components or bare wires should be at least 2 mm to one another and to the chassis, and 1 mm to the insulated surfaces.

15. Application of Electric Welding in Mounting of Circuit Elements

The electronics industry extensively uses welding to obtain *permanent joints*. Large- and medium-size units are welded from elements either taken from stock or after machining. Small-size parts are usually welded in the preliminary assembly sections, i.e. after final machining. This order is characteristic mostly for the production of medium-grade precision radio devices, in which accurate finish of the surfaces is not required.

In radio-components industry use is made mostly of electric welding processes (spot, seam, upset arcwelding); gas welding is employed much rarer.

Spot welding is employed for lap-joining of sheet material. Components from sheet steel of low-carbon grade up to 10 mm thick can be welded; non-ferrous metals (aluminium, copper alloys, etc.) for spot welding should be not thicker than 3 mm.

The spot-welding process features high productivity, though components or units of box-like construction jointed by means of spot welding are not hermetically tight. Besides, spot welding induces stresses, particularly, in the weld spots and for this reason high-precision components often cannot be connected using this technique.

As a result of spot welding, characteristic round depressions, i.e the imprints of the butt ends of the electrodes

remain on the surface. In case of considerable overheating of the metal, the imprints are deep and are difficult to be removed by cleaning or grinding.

Seam welding is employed when it is necessary to obtain tight lap joints. In this process the stocks or parts to be joined are fed between roller electrodes which leave a continuous track-like seam.

Upset welding ensures a reliable joining of components or stocks of different metals. In butt-resistance welding the components brought together with their butt faces are heated by an electric current passing through the junction, and, on reaching the plastic state, are tightly pressed together, thus ensuring a strong joint.

Flash welding consists in fusing the components and pressing them together either under current or without it.

Electric arc welding is generally used to connect sheet components and elements of considerable thickness and dimensions, as well as for joining components of intricate configuration which cannot be welded otherwise. Electric arc welding is resorted to for joining bodies and box-shape components, brackets and instrument racks, etc.

Arc welding of very thin sheet components (from 0.5 to 1.0 mm) has always been something of a problem. The welding is realized with the aid of a low-power welding generator ensuring a stable arc at welding currents of 20 to 50 A.

A new trend in the development of radio engineering is the introduction of automatic welding for wiring operations. In addition to lower consumption of labour, automation sets up conditions for designing flat units which are more convenient for mechanization and automation of the mounting and wiring operations as a whole.

Automatic and hand welding of wires utilize the heat of an electric arc to obtain permanent joints of metals. The wires to be welded are placed into the holes of a plate or welding fixture and are reliably pressed by clamps to obtain a good contact.

A diagram of automatic welding and formation of welde[illegible] joints is presented in Fig. 68. Assembly unit [illegible] 1 wit[illegible] unit 4 to be welded is placed on the base of [illegible] ure [illegible] and is pressed to the latter by clamps 2 [illegible] o[illegible]

flat carbon electrode *5* is arranged under the wires to be fused.

When the electrode approaches the projecting wires of the components *6* to be jointed a welding arc is formed between the electrode and one or several conductors. Due to a continuous movement of the electrode in the required direction all joints are welded in one stroke. As soon as

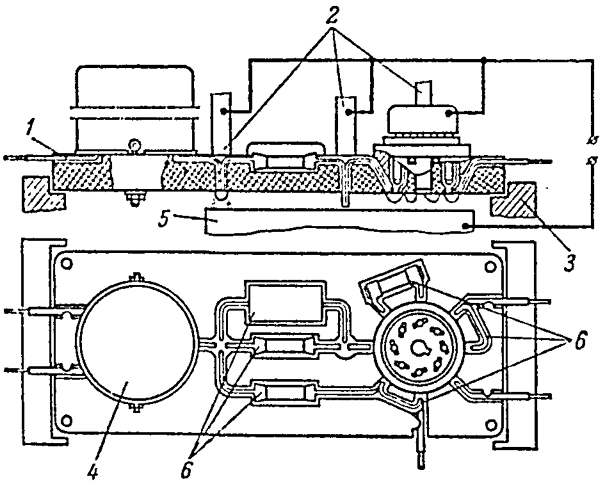


Fig. 68. Diagram of automatic welding and formation of welded joints

the carbon electrode reaches the limit position, the arc is broken and welding stops.

Usually in the process of automatic welding of connecting wires either the group or the conveyer belt technique is employed. The first method is better suited for welding electric wiring of individual units with several joints, the second—for welding complicated assemblies with a large number of joints. The schematic process of formation of the welded joint by group and conveyer welding technique is shown in Fig. 69*a* and *b*.

In group welding (Fig. 69*a*), leads *1* of the unit mounted must be prepared beforehand—cleaned, cut and bent as required. The leads thus prepared are laid down into weldin

fixture 2 in which special clamps 3 press the leads of the components together, forming a joint. To ensure the proper bunching of the lead ends to be welded and protecting the components from carbon dust and metal sputter in certain designs special heat screens are provided. Welding is achieved with flat carbon electrode 4 under unstable arc conditions. Arc excitation at the instance of carbon electrode

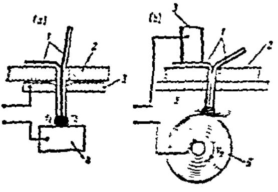


Fig. 69. Formation of welded joints using the group (*a*) and conveyer line (*b*) welding technique

contact with conductors is facilitated by electrode vibration with a rate v_1 besides constant speed movement at a rate v_0.

In conveyer belt welding (Fig. 69b) components *1* of the unit under assembly are subjected to the same preparation treatment as for group welding and are laid into the base of fixture 2. The ends of the leads of components *1* (or of units) are passed through special holes in the base. The diameter of the holes and their depth must ensure the assembly of the ends into compact bundles required for obtaining high-quality joints. The base of fixture 2 is pressed to conveyer 5 by holder 3.

Welding is performed with the aid of disk electrode 5 rotated at a constant speed in a direction opposite to the advance of the joints being welded. To facilitate stable excitation of the arc under a continuous feed of joints to be welded, a high-frequency voltage is superimposed on the arc welding voltage.

flat carbon electrode *5* is arranged under the wires to be fused.

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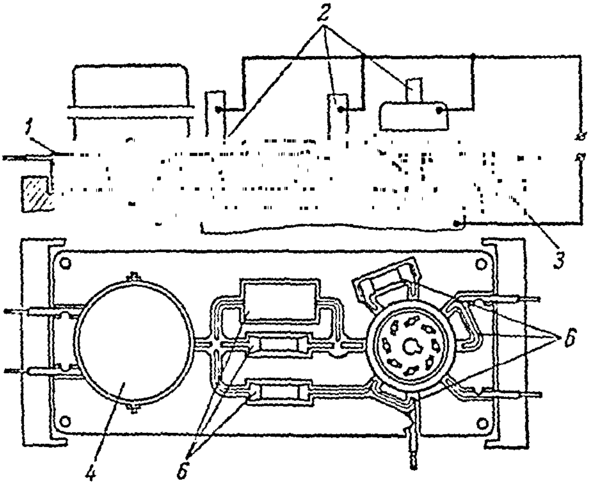


Fig. 68. Diagram of automatic welding and formation of welded joints

the carbon electrode reaches the limit position, the arc is broken and welding stops.

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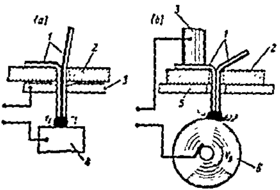


Fig. 69. Formation of welded joints using the group (a) and conveyer line (b) welding technique

contact with conductors is facilitated by electrode vibration with a rate v_t besides constant speed movement at a rate v_o.

In conveyer belt welding (Fig. 69b) components 1 of the unit under assembly are subjected to the same preparation treatment as for group welding and are laid into the base of fixture 2. The ends of the leads of components 1 (or of units) are passed through special holes in the base. The diameter of the holes and their depth must ensure the assembly of the ends into compact bundles required for obtaining high-quality wiring. The base of fixture 2 is pressed to conveyer 5 by holder 3.

Welding is performed with the aid of disk electrode 6 rotated at a constant speed in a direction opposite to the advance of the joints being welded. To facilitate reliable excitation of the arc under a continuous feed of joints to be welded, a high-frequency voltage is superimposed on the arc welding voltage.

The unit is assembled and welded in special assembly trolleys *4* placed on the conveyer installation (Fig. 70) equipped with a welding head. The electric current is fed to each joint via vertical tag-type leads which come into electric contact with the rotating disks of a special contact device during conveyer motion.

Group or conveyer welding conditions are selected depending on the number of welded joints and the cross section

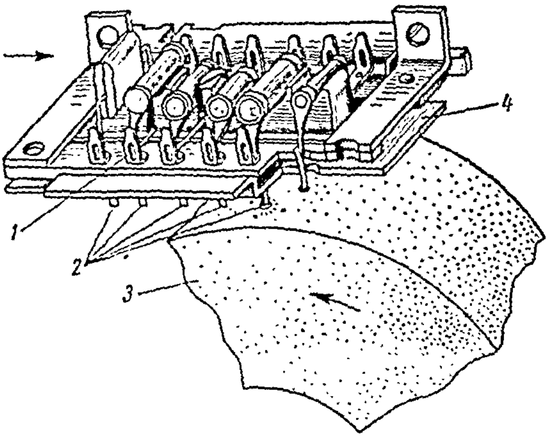


Fig. 70. Conveyer line installation with a weldi g head for assembly and welding of a unit

of the metal. The welding heads are powered from a standard transformer at idle current voltage of 20 to 40 V. Carbon feed rate is adjusted by the operator in the process of welding.

Speed v of feed of the parts towards the rotating carbon disk on the conveyer installation with the welding heads depends on the speed of rotation of the drive station rotary shaft. The speed of rotation of the carbon is constant (between 6 and 10 rpm). Carbon electrode *3* is made of the graphitized substance used in arc furnace rods.

To ensure good welding of the assembly joint, the metals of welded components *2* installed on block *1* should be selected in proper combinations and percentages. Notable for good weldability are combinations of copper-copper, copper-

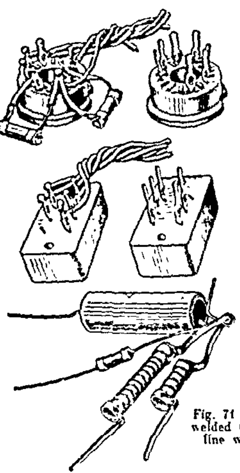


Fig. 71 Radio components welded using the conveyer line welding technique

bronze, copper-tombac (copper and zink alloy), copper-brass, tombac-bronze. Silver or tin-lead coatings on the leads welded improve the structure in the fusion zone, forming alloys, ruling out possible burning of the copper conductors and retaining their mechanical strength. After welding the joints are cleaned of deposited carbon dust and oxides with the use of a rotating brush. The welding head is installed underneath the conveyer belt.

Units welded with the use of conveyer line welding are illustrated in Fig. 71. The employment of welding heads for joining radio units greatly improves the quality of the

joint, at the same time reducing labour costs by 2 to 5 times (Table 5).

Table 5

Consumption of Labour in Assembly, Soldering and Welding Operations (Manual and Automatic Methods)

Unit	Hand soldering or welding, per 100 pcs		Automatic welding, per 100 pcs		Reduction in required labour	
	Operation	Time, hrs	Operation	Time, hrs	Per operation	Total
Tube socket	Assembly Soldering	2.35 2.35	Assembly Welding	1.14 0.11	2 times 21 times	3 times
Dynamic loudspeaker block	Assembly Soldering	0.57 1.3	Assembly Welding	0.31 0.14	1.85 times 9.3 times	3.43 times
Capacitor and resistor unit	Assembly Welding	0.95 0.3	Assembly Welding	0.33 0.05	2.85 times 6 times	2.6 times
Intermediate-frequency transformer	Assembly Welding	0.65 2.2	Assembly Welding	0.65 0.22	— 10 times	1.6 times
TV set "Svet" block	Assembly Welding	7.2 2	Assembly Welding	1.66 0.14	4.3 times 14.1 times	5 times

In designing assemblies to be jointed by automatic welding, the following should be taken into consideration:

all the contact joints should be arranged in one plane and on one side of the base;

the lead ends projecting beyond the base surface should be from 8 to 10 mm long;

the nature and volume of metal of the conductors to be welded should be selected on the basis of good weldability;

in case of the group welding technique the units are to be designed for assembly in fixtures with the use of clamps to compress the conductors and supply the welding current;

the unit design and all the hook-up elements should provide free access of the current-conducting clips to the conductors welded;

in conveyer line welding the joints should be arranged in a definite order so as to ensure successive current

supply to them via continuously transitory or gang contact fixtures with reciprocating movement synchronized with that of the conveyor;

the design of units for group or conveyor line assembly should provide maximum convenience and high speed of assembly of the parts.

18. Glued Joints

The need to obtain strong joints of different materials (plastics, ebonite, rubber, glass, etc.) in any combination necessitated the development of various adhesive materials. In addition to the mechanical strength imparted to the joint, adhesive materials, depending on the application and operating conditions, must also possess high insulating properties, elasticity, moisture resistance, have constant physical and chemical properties, and also retain the required strength of the joint within a wide temperature range.

Adhesive materials (glues) extensively used in radio engineering are cited in Table 6. In addition to the glue designation, the glue composition, adopted methods of cementing with different glues, properties of the cementing layer and the field of application are listed. Thus the appropriate type of adhesive material and procedure of cementing are selected depending on the requirements which this or that joint must meet.

The parts to be joined by gluing are dried, thoroughly cleaned of dust and dirt, following which their surfaces are matched, carefully wiped, and degreased. The parts are cleaned with organic solvents or by mechanical treatment.

To apply the cement, a glass stick, or brush, or pulverizer may be used. 5 to 10 min after cement application the surfaces should be brought into close contact to uniformly spread the glue over the surfaces and squeeze out air bubbles possibly trapped between them.

Usually the glue is applied in two steps; the second application is in 50 to 60 min. The thinner and the more uniform is the layer of glue, the stronger is the joint. For greater reliability the components are [illegible]sed, and held so from 24 to 72 hrs (depending on the s[illegible] components and the type of glue).

Adhesive Materials Used

Adhesive material	Composition	Technology of gluing process
Bakelite varnish	Alcoholic solution of phenolformaldehyde resin	Polymerization by rising temperature in steps from 110 to 150°C. Pressure at gluing from 3 to 5 kg/cm²
Methanol glue	Methanol + benzoyl peroxide or nitric acid from 1 to 3% by weight	Polymerization at 20±5° C
Cement БФ-2	Alcoholic solution of phenolformaldehyde resin with certain additives imparting various properties to glue	Polymerization at gradually rising temperature from 60 to 120°C. Pressure at gluing from 5 to 10 kg/cm²
Cement БФ-4	Same	Polymerization at 60°C. Pressure at gluing from 5 to 8 kg/cm²
Cement БФ-6	Same	Polymerization at 60° C. Pressure at gluing from 2 to 4 kg/cm²
Cement БФ-3 Cement БФ-5	Same	Polymerization at 100 to 130° C. Pressure at gluing from 0.5 to 1.5 kg/cm²
Polystyrene glue	20% polystyrene shavings, 80% benzene (by weight)	Gluing is due to evaporation of benzene. Pressure at gluing 2.5 to 3 kg/cm²
Acrylic glue	2-3% organic glass shavings, 97-98% dichloroethane (by weight)	Gluing is due to evaporation of dichloroethane. Pressure at gluing 2.5 to 3 kg/cm²
Thermoprene glue	Natural rubber treated with organic sulfo acids (10-12%) and composition of gasoline with benzene 88-90% (by weight), ratio 2 : 1	Gluing is due to evaporation of gasoline and benzene. Pressure at gluing 4-6 kg/cm² with simultaneous heating to 170°C. Thickness of gluing layer can be 1 to 2 μ
Epoxy glue	Epoxy resin ЭВ-4, diciandiamide and filling material	Polymerization at 150°C. Pressure at gluing from 5 to 7 kg/cm²

Table 6

in Radio Engineering

Properties of cementing layer			Application
Range of working temperatures, °C	Tensile strength, kg/cm²	Resistance to moisture, liquids	
−50 to +80	80-90	Resistant to transformer oil. Not moisture-resistant	Gluing of hardened paper, textolite, electric cardboard, plastics, wood in any combinations
−60 to +70	250	Resistant to transformer oil, gasoline and kerosene. Not moisture-resistant	Gluing of materials in any combinations Brass surfaces are glued after tinning
−60 to +80	50-200	Resistant to oils, gasoline, kerosene, mineral acids, moisture	Gluing of any metallic and non-metallic materials in any combinations
−60 to +80	50-140	Same Also resistant to heavy vibration	Same
−60 to +80	50-80	Same	Gluing of fabrics, cellophane, triacetin, celluloid, mica, etc.
−60 to +80	50-70	Same	Gluing of glass
−50 to +60	–	Resistant to moisture, acids and alkalies	Gluing of polystyrene, cementing of thin wires of induction coils
−60 to +50	110	Resistant to oils, acids, sea water	Gluing of organic glass
−40 to +70	50-100	Resistant to moisture, acids, sea water, heavy vibration	Gluing of different brands of rubber to metals Brass should be tinned prior to gluing
−70 to +150	60-180	Resistant to acids, alkalies, moisture	Gluing of metals and other materials in different combinations Cementing layer has packing properties (though not hermetic) Can be used under tropical conditions

Adhesive Materials Used

Adhesive material	Composition	Technology of gluing process
Bakelite varnish	Alcoholic solution of phenolformaldehyde resin	Polymerization by rising temperature in steps from 110 to 150°C. Pressure at gluing from 3 to 5 kg/cm²
Methanol glue	Methanol + benzoyl peroxide or nitric acid from 1 to 3% by weight	Polymerization at 20±5° C
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Cement БФ-6	Same	Polymerization at 60° C. Pressure at gluing from 2 to 4 kg/cm²
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−60 to +80	50-200	Resistant to oils, gasoline, kerosene, mineral acids, moisture	Gluing of any metallic and non-metallic materials in any combinations
−60 to +80	50-140	Same Also resistant to heavy vibration	Same
−60 to +80	50-80	Same	Gluing of fabrics, cellophane, triacetin, celluloid, mica, etc.
−60 to +80	50-70	Same	Gluing of glass
−50 to +60	—	Resistant to moisture, acids and alkalies	Gluing of polystyrene, cementing of thin wires of *induction coils*
−60 to +50	110	Resistant to oils, acids, sea water	Gluing of organic glass
−40 to +70	50-100	Resistant to moisture, acids, sea water, heavy vibration	Gluing of different brands of rubber to metals Brass should be tinned prior to gluing
−70 to +150	60-180	Resistant to acids, alkalies, moisture	Gluing of metals and other materials in different combinations. Cementing layer has packing properties (though not hermetic). Can be used under tropical conditions

CHAPTER THREE

WIRING

17. Essentials of Assembly and Wiring

Successful wiring of a radio apparatus requires that the rules of assembly and wiring operations are thoroughly observed. The assembler, when performing his work, must have a clear understanding of the operating conditions of the apparatus, and must ensure easy repair of the apparatus in operation or replacement of components, and check-up of the radio circuits.

The apparatus is assembled in strict conformity with the adopted technology, adhering to the following succession of wiring common to all kinds of radio equipment:

wiring of panels, switches and other isolated units (prior to fitting them to the apparatus chassis);

assembly of bare wire jumpers;

assembly of isolated wires;

mounting of preassembled units and fitting the wires running from them on the chassis;

laying out bunched conductors on the chassis and wiring the conductors;

wiring the hook-up radio components (resistors, capacitors, etc.).

In each particular case, however, the above-listed succession of assembly and wiring can be partially changed, if required.

Any apparatus must be fabricated in compliance with the drawings and specifications and adopted methods of production.

Still higher requirements are imposed upon the assembly of radio devices, as the quality of the assembly will guarantee proper output parameters which ensure reliable device operation.

The wire or cable ends are stripped of insulation with the use of special tools or contrivances which rule out possible cuts of the wire cores or individual cable conductors. The ends of the external textile braid of wires should be prevented from tousling and creeping.

The braided shields of electric wiring not exceeding 100 mm in length are connected to the body in one point, those longer than 100 mm—at two points and are grounded at both ends (except cases specified otherwise). The method of processing braided shields and of soldering grounding wires ("whiskers") to them must exclude the possibility of damage (burning) to the wire insulation. The edge of the braided shield should be at a distance of 1 to 2 wire diameters from the sliced insulation end with a voltage below 500 V, at a distance of 20 mm with that below 3,000 V, and 40 mm when it is above 3,000 V.

Untinned current conductors of wires and cables should be cleaned of oxide film prior to tinning.

Electric wires should be connected with the contact tags without stretching them, leaving a reserve of 7 to 10 mm at each end for another stripping and soldering operation. When elongating wires, they should be first connected by soldering and only then twisted.

Wires are connected between themselves and with the leads of hook-up elements only by means of terminal blocks or tags (lugs). Not more than three wires are to be soldered to one contact tag (including the leads of hook-up elements) and not more than two wires of no more than 1 mm^2 total cross section should be soldered to glass-seal contact lugs.

Rigid leads fitted into glass and ceramic components should not be bent in the process of wiring.

Multiconductor wire cores connected to clamping contacts are fitted with cable grips.

Washers should be placed between the cable grip and insulating plate, as well as under the nut or head of the clamping screw.

Bantam tube socket lugs and other "floating" lugs are wired with a master form or defective tube inserted into the sockets thus fixing the lugs in position.

Wire connections up to [illegible] mm in length can be made with bare wire laid along the shortest distance between the

lugs (without sagging). The minimum spacing between bare wires and chassis depends on the working voltage and is specified in flow charts; it should comply with the given below:

Operating voltage, V	up to 127	220	380	500
Minimum spacing, mm	3	5	7	9

Jumpers of bare wire and the leads of hook-up radio elements are insulated with polyvinylchloride tubing only in case of possible short-circuiting either between themselves or with adjoining surfaces, and this should be specified in the flow chart.

It is not recommended to use rigid wires for connections between the lugs of elements which can shift with respect to one another due to vibrations or jerks, as well as between floating lugs (as, for example, between floating lugs of bantam tubes, etc.). The wire insulation must not be damaged; if so, it should not be mended with insulating tape or varnish.

Care must be taken to ensure a sufficient spacing (not less than 5 mm) between certain components (e.g. vitrified resistors) and movable elements. Electric wiring in the immediate proximity to components emitting heat must be with heat-resistant insulation cables. The cotton insulation of wiring must not get in touch with non-insulated wiring elements (cable cores, contact tags). If shielded wires may come in contact with non-insulated sections of the circuit, they must be provided with a coating in the form of insulating tubes.

Two or more electric wires (shielded wires as well) should be bound into a bunch. Each branching of wires from a bunch of conductors must be tied. The knots of cotton thread loops made on a forming board should be arranged on the lower portion of the bunched conductors (on the side facing the chassis). A.c. circuit supply conductors (50 and 400 c/s frequencies) are twisted in pairs over their entire length prior to bunching. The bunched conductors must not lie on fastening parts (nuts, screws, clips), obstructing access to the latter.

The radius of bending of leads of the hook-up components should be not less than their doubled diameter (thickness).

Abrupt bends of the leads and bends at a level with the component casing are impermissible. The length of the leads of hook-up resistors and capacitors from the casing to the soldering point should be from 8 to 15 mm. The leads of semiconductor elements are bent and soldered at a distance of not less than 10 mm from their bodies.

In wiring transistors their base contact is connected first. In mounting polarized parts (all types of ДГ-Ц semiconductor diodes, electrolytic capacitors) the proper polarity of their leads must be observed.

The hook-up elements are spaced from each other and from all other current-conducting surfaces at not less than 2 mm. This distance can be reduced to 1 mm, if a coating of the wiring with moisture-resistant enamel is specified. The hook-up parts should be connected so as to make the nominal value designations and the marking well visible; in case of assembly on panels the inscriptions should face one direction. Connecting wires, bunched conductors, and hook-up elements should not obstruct reading of marking inscriptions.

In soldering wire connections a reliable contact and the required mechanical strength must be ensured.

Finished wiring must be carefully cleaned of dust and dirt.

18. Operator's Work Bench

The work bench of an operator is at a table or bench provided with all necessary equipment and fixtures. Proper arrangement of the work bench is of great importance, influencing the efficiency and quality of the operator's work.

It should house tools, components, subassemblies and accessories required for carrying out the current work. An example of lay-out and equipment of an operating bench is presented in Fig. 72. The equipment is intended for carrying out operations of average labour consumption (lasting more than 3 min) and is used in the flow-line production both with manual and mechanized station-to-station transfer.

Storage boxes are a handy supplement to the operating bench; they are used for storing fastenings (nuts, screws,

washers, rivets) and circuit elements required for assembly. They can be of diverse shapes. Illustrated in Fig. 72 are a mounted and a flat boxes *3* made of sheet steel.

The tools are arranged in drawers *14* of the bench in strict order of application. Measuring, wiring, mounting and fitter's tools must not be stored all in one box. If

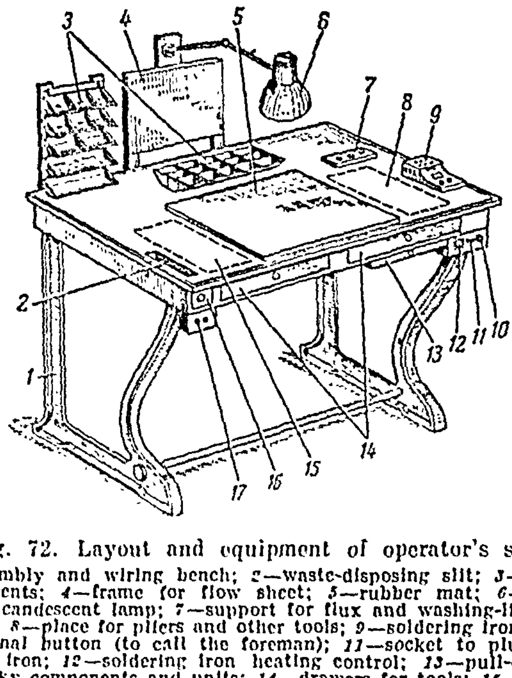


Fig. 72. Layout and equipment of operator's station

1—assembly and wiring bench; *2*—waste-disposing slit; *3*—cells for components; *4*—frame for flow sheet; *5*—rubber mat; *6*—reflector with incandescent lamp; *7*—support for flux and washing-liquid containers; *8*—place for pliers and other tools; *9*—soldering iron support; *10*—signal button (to call the foreman); *11*—socket to plug in soldering iron; *12*—soldering iron heating control; *13*—pull-out shelf for bulky components and units; *14*—drawers for tools; *15*—place for forceps, heat-removal caps, rosin-core solder; *16*—waste bin; *17*—probe socket

kept "in bulk", the tools (measuring instruments in particular) can be damaged, much time is wasted to find the required tool, whereas the working station acquires an untidy appearance.

The arrangement of tools in each box should also be well thought out. The best practice is to keep each tool in the box in its special recess like those made in the case for drawing instruments. Measuring instruments are usually

distributed from the tool-room in special cases or boxes, thus no recesses in the work-bench drawers are required for them.

Sometimes a vice is fastened at the right-hand side of the bench; it is used for miscellaneous operations which might be necessary in the process of assembly and wiring of radio equipment (such as fabrication of clips for securing capacitors, stretching single-core electric wires, etc.).

The soldering iron is placed on support *9*. In modern practice electric soldering irons of various designs are used for wiring operations. In accordance with the safety rules soldering irons rated at no more than 36 V must be used. In assembly shops a special line fed from a step-down transformer is laid along the assembly conveyer to supply current to soldering irons.

The mains of a plant usually fluctuates over a wide range of voltage values during the day and night. Due to these fluctuations the soldering iron will be heated to different temperatures which might result either in underheating or overheating. The required temperature is usually maintained with the use of tapped secondary windings on the transformers.

The operator's bench is equipped with panel *11* having several plug sockets which are supplied with voltage from different taps of the transformer secondary winding (Fig. 72), to which the soldering iron is connected. In supplying the soldering iron from an individual transformer, designed for power supply of one work bench only, the transformer is placed on the operator's bench. In both cases check that the flexible cord is located beyond the bench and the soldering iron can be moved about freely.

The soldering iron support is made in the form of a box divided into two sections: for the flux and for the solder. A sheet of pressboard or hard paper (discarded together with the contaminated flux) is placed on the box bottom. The amount of flux in the box should not exceed 4-5 cm^3 which is sufficient for immediate use and enables its more complete utilization and more frequent refreshment. The quantity of solder in the box should not be excessive either, since a large lump of solder may become fouled with the carbon and oxide from the soldering iron bit, requiring

more time for melting. Contaminated solder is collected in one place and remelted.

The operator's bench should be well illuminated by natural light, therefore it should be located close to a window. In case of artificial lighting the lamp rating should be not more than 40 to 60 W. Such a lamp will ensure proper lighting of the bench at a distance of 0.5 to 0.75 m from the illuminated surface. The light from the lamp should fall uniformly so that there are as few shadows as possible. Particularly important for proper illumination of the station is the absence of flashes which dazzle the eyes (due to excessive brightness of the lamp).

The light source and lighting fixtures are located so as to completely protect the eyes from direct rays. Lighting fixtures providing uniform illumination and excluding dazzling are used. Most handy are fixtures with an extension or rotary bracket and deep reflector *6* in which the lamp is fully recessed (Fig. 72). These fixtures enable the reflector with the lamp to be placed over the work bench at a required height and provide lighting in the required direction.

The flow chart is placed in frame *4* on a special bracket so that it can always be at a moment's notice. The workpiece is placed within the easy reach.

Deleterious vapours and burnt products formed during soldering or welding are removed with the aid of exhaust ventilation provided at the operator's bench. If arc welding is used in the assembly processes the operator's bench is provided with special screens or curtains protecting the operator's eyes from the arc light coming from the neighbouring stations.

To protect the apparatus from damage in the process of assembly, foam rubber mat *5* is placed on the operator's bench; inflammable liquids (spirits, varnish, glue) are kept in a metal box.

19. Assembly Tools

There are two basic kinds of assembly operations: assembly of serial equipment in an assembly shop on the production line and assembly of mock-up and pilot models of the apparatus in a laboratory or experimental shop.

An operator in an assembly shop, wiring units of mass-produced radio equipment, does not need to carry out complicated mechanical work, install and secure bulky parts and units (lamp panels, transformers, switches, plug connectors). These operations are carried out by assembly fitters.

The assembly worker is to perform only wiring and simple fastening operations such as laying wires between components and units of the radio apparatus, mechanical fastening of the wires to the lugs, as well as arrangement and installation of the small-size circuit elements, fitting and fastening the leads of the components to the lugs of the panels, terminal blocks, etc. For these operations the operator needs only such tools as a soldering iron, flat-nose pliers, round-nose pliers, side-cutters and a screw driver.

The radio fitter working in a laboratory or experimental shop, before wiring a unit or subunit, generally has to assemble it completely first, i.e. to install and fasten all the components and elements, to locate all the wiring plates and bearing points, drill holes which might be required in the course of assembly, etc. In addition, the universal assembler has to mount and secure components and devices as well as to assemble and wire them. These operations require a much greater outfit of tools.

Let us discuss in detail the assembly and wiring tools required.

Soldering irons. Soldering joints in the course of radio equipment wiring is usually performed with the use of continuous-action electric soldering irons whose heating element is in the form of a nichrome spiral either wound round the soldering iron copper rod or located inside it.

The electric soldering iron should ensure an intensive supply of heat to the place of soldering. This is effected by an appropriate selection of the heating element rating and the mass (diameter) of the copper rod which must have sufficient thermal capacity and rapidly heat the soldered material without any significant drop of its own temperature at the same time.

Not less than two soldering irons should be included into the tool set. One of them, with a 60 to 100 W rating and a rod from 10 to 12 mm in diameter, is used for ordinary wiring operations (such as soldering wires up to 1 mm dia)

and the other, with 200 W power rating and a thicker rod, is used for soldering thick conductors, screens of sealed transformers, screens of intermediate-frequency filters and other components requiring more intensive heating. For wiring use should be made of soldering irons designed for supply from a step-down transformer at 12, 24 or 36 V. Soldering irons designed for supply from 127 and 220 V mains are not recommended since in case of rupture of insulation between the heating element and the rod the operator might receive a dangerous electric shock.

When wiring transistorized equipment the soldering iron rod should be reliably grounded, so as not to cause damage to the transistors in case of faulty insulation of the soldering iron heater.

The reduction in length of the soldering iron copper rod as a result of frequent cleaning, on one hand, and the connection of a number of soldering irons to one transformer, on the other hand, can cause either underheating, encumbering the soldering, or overheating, when the solder rolls off the copper rod and the heating elements burn out. The most favourable operating conditions of the soldering iron are maintained by voltage control.

An iron for soldering connection wires should heat quickly (not more than in 1.5 min after switching on); it should also be of light weight at a sufficient rating. Its design should ensure easy replacement of the burnt rod; the handle should not get hot in operation.

Two types of electric soldering irons, straight and angular, are in common use for the wiring of radio equipment. The angular iron (Fig. 73*b*) is more handy for soldering open joints (on terminal blocks, cable lugs, plug connectors); the straight irons (Fig. 73*a*) are handy for soldering wires inside the apparatus, in tight places, inside units with deep chasses and close wiring. Extensively employed in wiring radio equipment are straight soldering irons with shaped copper rods intended for the performance of special jobs.

Figure 73*b* represents an angular soldering iron of 60 W rating with a copper rod 8 mm in diameter. The length of the rod (up to 150 mm) is greater than that required for immediate use since allowance is made for subsequent

wear. The rod is secured with an eccentric clamp and is extended as it wears off as a result of dressings.

Sometimes soldering irons with changeable copper rods are employed. One of these illustrated in Fig. 74 has internal heating element *3* in the form of a nichrome wire helix

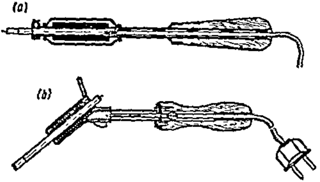


Fig. 73. Types of soldering irons
a—straight; *b*—angular (bent)

enclosed in copper cup *2*, provided with changeable tip *1* and packed with magnesium hydroxide. The helix should be arranged concentrically providing a uniform thickness of the insulation layer between the heating element and



Fig. 74. Electric soldering iron with replaceable tip and heating element inside the rod

cup. Electric current heating the helix passes through the connecting stainless steel tube *4* secured in handle *5*.

With hand soldering irons, much time is spent picking up solder with the copper rod. To increase the productivity of labour, experiments have been made on mechanization of this process by automatic feed of solder either to the working portion of the soldering iron copper rod or directly to the joint.

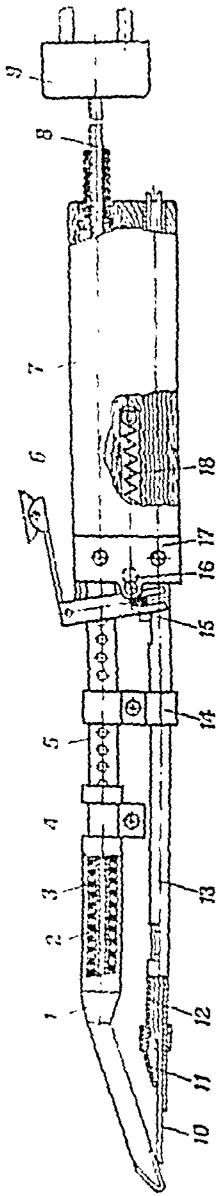


Fig. 75. Electric soldering iron with semiautomatic feed of solder

The author jointly with engineers G. V. Kalashnikov and V. I. Ivanov have developed an entirely new type of electric soldering iron fitted with a device for semiautomatic supply of rosin-core solder to the working portion of the copper rod, protected from burning and erosion by a nickel bit (Fig. 75). The solder is fed due to translatory movement of a pusher. The button, actuating the solder feed mechanism, is located on the soldering iron handle and is linked to the pusher by a lever. The solder feed is adjusted by an eccentric whose rotation ensures continuous control of the amount of solder fed.

This electric soldering iron consists of a rod, heating element, feed mechanism with a button and return spring, solder feed control, handle and flexible electric cord with a plug. Rod *1* with a protective nickel bit is fastened on tube *5* with the aid of clamping collar *4*. Heating element *3* insulated from the rod by mica *2* is located inside the rod.

The heating element consists of a nichrome wire wound on a ceramic tube; it ensures heating of the rod to a temperature up to 350°C. Soldered to the ends of the nichrome wire helix are two copper conductors connected to flexible cord *8* with plug *9* at the end. The copper conductors located inside tube *5* are insulated by means of mica washers and asbestous cord. Tube *5*

with cooling holes and tube *13* with the solder are fastened in handle *7* by means of set screws.

When button *6* is depressed translatory motion through lever *15* is transmitted to pusher *12* which moves solder *10* to the working portion of rod *1*. Simultaneously with the translatory motion of pusher *12*, return spring *18* is stretched out. Upon releasing button *6*, spring *18* returns lever *15* and pusher *12* to the initial position. The task of preventing solder *10* from moving in the reverse direction during the return motion of pusher *12* is accomplished by lock *11* secured on tube *13* by a ring. Solder feed control *16* is fastened on ring *17* which fits around handle *7*. Upon turning control *16*, the position of the eccentric changes, smoothly varying the stroke of pusher *12* and hence the feed of solder *10*. The rigidity of the design is achieved by fitting split collar *14* which also serves to retain a preset spacing between tubes *5* and *13*.

This type of electric soldering iron has been tested in production shop conditions; in comparison with the standard soldering irons it ensures an increase in productivity of labour by *20* per cent, saving in solder by *5* per cent, and provides a higher quality of joints in terms of shape and strength.

Electric soldering irons are designed for soldering joints up to 5 cm in volume with the use of rosin-core and wire tin-lead solders; their voltage rating is 12 V, and power rating—35, 70 and 120 W. Rod temperature is from 290 to 350°C, diameter of the solder used—from 1 to 4 mm, working copper rod diameter is 4, 6 and 8 mm.

Flat-nose pliers. Usually a set of assembly and wiring tools includes two flat-nose pliers. The bigger one, sizing from 150 to 170 mm, has knurled jaws (Fig. 76*a*) and is used for stretching or straightening thick single-core wires, bending various fastening clips and other similar jobs. The smaller pliers have thin and narrow jaws from 40 to 50 mm long (Fig. 76*b*); the jaws are not knurled so as not to damage bare wires and wire insulation during bending and fitting.

Round-nose pliers. These also come in two pairs with long and thin jaws up to 40-50 mm long and 1.5 mm in diameter at the ends and 5 mm at the jaw base (Fig. 76*c*). The

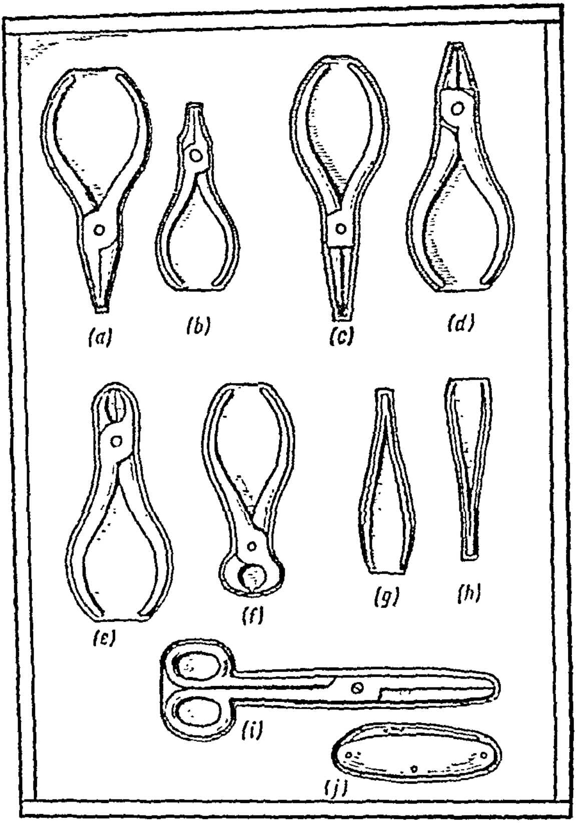


Fig. 76. An example of a tool drawer

a—notched jaw pliers; *b*—plain jaw pliers; *c*—pliers with long and thin jaws; *d*—notched, strong-jaw round pliers; *e*—side-cutting pliers; *f*—front-cutting pliers; *g*—surgical forceps; *h*—watch-maker's pincers; *i*—scissors; *j*—electrician's knife

pliers are handy for curling wire leads into spirals. Another type of pliers, sizing 150 mm with strong jaws 30 mm in length, are knurled on the converging surfaces (Fig. 76*d*). The diameter of the jaws of such pliers is 7 to 8 mm at the base and 3 to 3.5 mm at the ends. These round-nose pliers are used for handling bare wires 1.5 to 2 mm in diameter; they are also convenient for bending wire ends into rings for fastening them with screws and nuts.

Cutting pliers. Most suitable for wiring operations are side cutters or nippers (Fig. 76*e*) which can be used for cutting odd ends of wire inside the apparatus. The cutting jaws of such pliers must be very sharp and straight. Nippers can be used for cutting wires not over 2 mm in diameter.

Larger gauges of wires are cut with the help of front-cutting pliers (Fig. 76*f*). These are less suitable for wiring operations, since their cutting jaws are arranged at right angles. Such pliers, though being stronger, are sometimes inconvenient for cutting wire. The side- and front-cutting pliers usually come in the same sizes (not over 150 mm). For operation with thicker wires it is advisable to have front- cutting pliers 200 mm in size.

Forceps. These are indispensable in operating radio equipment. Usually surgical forceps (Fig. 76*g*) not more than 130 to 140 mm in size and watch-maker's forceps (Fig. 76*h*) are used. The forceps should be sufficiently springy. The watch-maker's forceps have sharp converging prongs and are used with wires from 0.03 to 0.08 mm in diameter (for trimming and fitting the ends of potentiometer windings, circuit coils, etc.). The more sturdy surgical forceps with notched prongs are used for other wiring operations (twisting the ends of wires around parts, straightening wires and fastening them to components, holding wires in the process of soldering, etc.).

Very convenient for assembly and wiring operations in difficult-to-reach areas are surgical forceps with a rectangular collar fitted on the prongs. The collar clamps the prongs, when moved towards their ends. A resistor, capacitor, wire or other component can be gripped by the prongs and fixed in this position by adjusting the collar; this provides some convenience, since the forceps can be easily held by the very top.

Scissors. These in sizes from 150 to 200 mm (Fig. 76*i*) are necessary for cutting paper or fine fabric. The cutting edges of the scissors should be not less than 50 mm in length, be sharp and tight-adjusted. Such scissors are useful for cutting paper (for interlaying transformer coils and other wound components), varnished fabric, binding thread, etc.

It is advisable also to have small hand-operated shears for cutting sheet metal (aluminium, brass, iron, copper up to 1 mm thick). Such shears should be from 250 to 270 mm in total length with the blades from 90 to 110 mm. The internal side surfaces of the blades should be well polished and parallel; the cutting edges of the blades should be sharp, otherwise they will crumple the metal instead of cutting it. It is not recommended to cut metals thicker than 1 mm since this may damage the shears.

Electrician's knife is also included into the tool set. It may be of a length between 150 and 170 mm, with one

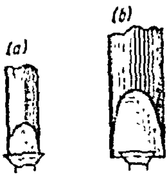


Fig. 77. Selection of screw driver size

a—screw driver of proper blade width; *b*—blade wider than screw head slit; *c*—blade narrower than screw head slit



Fig. 78. Screw driver

or two blades (Fig. 76*j*). The knife is used for stripping the wires (if other methods cannot be used), for chipping threads ˜ter winding the insulating tape and for other similar ˛obs.

Screw drivers. These are used for fastening radio elements, panels, bearing points, plugs. They should match the slot of the screw head (Fig. 77*a*). Thus, if a flat head screw is worked with a screw driver whose blade is wider than the length of the slot (Fig. 77*b*), the surface of the panel or component, into which the screw is inserted, may be damaged by the projecting ends of the blade. W[illegible]n the screw driver is narrower than the length of [illegible] (Fig. 77*c*), it is difficult to tighten up the screw p[illegible] and an attempt to do so may result in damaging t[illegible] head (stripping the slot) or breaking the screw [illegible]

Four or five screw drivers of different length should be in the radio operator's tool kit (Fig

from the side only. The tool set should contain five wrenches of both types for nuts M2, M3, M4, M5 and M6 and a side wrench for nuts M10 (for fitting variable resistors and tumbler switches).

Hammers. The tool set should include an ordinary fitter's hammer weighing 200 to 300 g with a hard wood handle (of birch tree or oak), and 230 to 250 mm in length

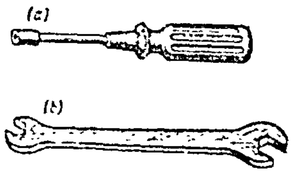


Fig. 80. Wrenches
a—socket wrench; *b*—usual ("monkey") wrench

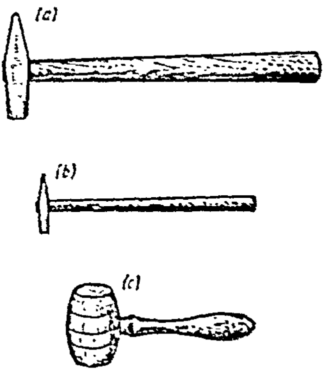


Fig. 81. Hammers
a—fitter's hammer; *b*—watch-maker's hammer; *c*—mallet

(Fig. 81*a*). This hammer comes handy when it is required to bend sheet metal in a vice (brass, alumin), fabricate chassis, prick holes for drilling, and to carry out many other fitter's jobs.

In addition to the fitter's hammer, a smaller, watchmaker's hammer (Fig. 81*b*), is necessary. It is used for driving in pins, cupping out small rivets and other operations in which the heavier hammer cannot be used.

It is also useful to have a mallet made of hard wood—birch or oak (Fig. 81*c*). This will be indispensable for such jobs as straightening of bent or buckled stock from strip or sheet metal (aluminium, brass, red copper) from 0.5 to 2 mm thick used in the production of chassis, screens, etc. The mallet does not leave hollows or indentations on the metal surface.

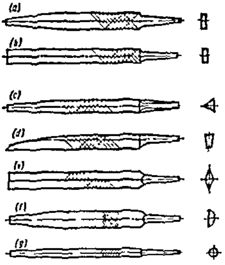


Fig. 82. Files
a—flat, pointed; b—flat, blunt; c—triangular; d—knife file, e—rhomboidal; f—half-round, g—round

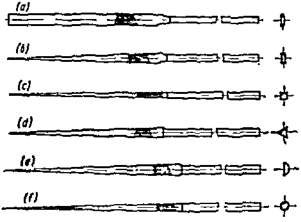


Fig 83. Needle files
a—flat; b—taper flat, c—square, d—triangular; e—half-round; f—round

Files are used for cutting and smoothing metal, when fabricating chassis, making holes, fitting parts and cleaning soldering irons. Files of different types and shapes should be available (Fig. 82).

Files come in various lengths (from 75 to 450 mm). By the length of a file the length of its cut portion is implied. Files of medium length (150-200 mm) are most convenient in radio work. The round file should be not over 8-10 mm in diameter. After filing metal (aluminium or copper), hardened paper or textolite parts the file should be cleaned of particles of the material stuck to the cut with a special card brush. Files are kept separately from other tools in special recesses.

Needle files are made of thin steel wire. A set of five or six needle files is adequate to meet the operator's requirements.

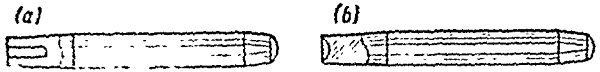


Fig. 84. Tightener (*a*) and shape die (*b*) for riveting

They have shapes similar to those of ordinary files (Fig. 83) and the length between 140 and 160 mm. Half of the length is provided with bastard, smooth or barette cuts; the other



Fig. 85. Prick punch

half (round section) is used as a handle. Needle files are employed for fine and precision work—cutting holes, slots, etc.

Rivet sets and snaps. Rivet set (Fig. 84*a*) and rivet snap (Fig. 84*b*) are the tools used for riveting parts in the process of radio equipment assembly. The rivet set serves to tighten or press parts to one another and to the rivet head; the rivet snap is used to impart the final shape to the rivet closing head. Rivet sets and snaps of different size may be required.

Prick punches. The prick punch (Fig. 85) is a round bar made of tool-grade steel: one end of the bar is tapered at

an angle of 45 to 60°; its middle section is cut for better
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and align the drill.

Scraper. This tool is necessary to remove burrs left after cutting large holes (for tube sockets, plug connectors, etc.).

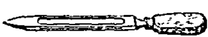


Fig. 86. Scraper

The best is a triangular scraper with three cutting edges (Fig. 86). It can be made out of an old triangular file, 100 to 130 mm in size, after grinding off the cutting ridges and sharpening the cutting edges retaining the triangular profile of the file. For convenience the scraper tang is fitted with a wooden or plastic handle.

Tools for laying and adjusting the wiring. The pin (Fig. 87*a*), rest (Fig. 87*b*), straight and right-angle hooks (Fig. 87*c* and *d*) are used for pressing down the wires during soldering or welding, for threading individual wires or bunches through holes in the chassis walls, for drawing a conductor out of a bunch, as well as in all cases of laying the wires in position.

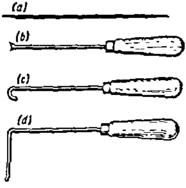


Fig. 87. Tools for wiring fitting and adjusting

a—pin, *b*—support, *c*—straight hook, *d*—straight-angle hook

Marking tools. In laying out the chassis and panel of a radio apparatus model the operator uses a straight-edge, protractor, square, compasses and a scriber. The latter is a sharp-pointed rod of tool-grade steel 3 to 4 mm in diameter and 100 to 130 mm in length. The opposite end of the tool is fitted with a brass cut handle. Sometimes the scriber is used instead of an awl for piercing holes

Measuring tools. Slide calipers graduated to 0.1 mm are used to measure external and internal diameters of parts, mark out holes for tube sockets on the chassis during modelling and such-like operations. The diameters of wires for power transformers, coil chokes, potentiometers, and the diameters of wires connecting components and units are measured by means of micrometers. The slide caliper and micrometer are delicate instruments requiring careful handling. Occasionally they should be wiped with a soft cloth and coated with clean petrolatum; they are kept in special cases.

20. Connecting Wires

In mounting radio equipment use is made of copper wires. The wires must be flexible to permit "shaped laying" (bending to a certain shape) of individual cables and bunched conductors consisting of several wires tied together. For greater flexibility conductors are made in the form of several individual thin conductors twisted together. The diameter and number of thin conductors are selected depending on the intended use and required cross section of the cable.

Connecting wires are insulated with the use of rubber, glass fibre, polyvinylchloride, cotton, silk and other materials.

Connecting wires, mainly those with rubber insulation, have tinned conductors. They are tinned to protect the copper from the effects of sulphur contained in the rubber, since formation of copper sulphate in the surface layers of the copper conductor results in an increase of its resistance and decrease in mechanical properties. The rubber insulation is characterized by a rapid decrease in elasticity, so cracks may appear on the bends of wire causing breakdown. In addition, tinned conductors are well soldered without stripping wire ends, thus considerably speeding up the wiring process and reducing costs. Non-tinned wires are also used.

The thickness (gauge) of connecting wires is selected depending on the current density and frequency; the type of insulation depends on the voltage rating and operating conditions.

Connecting wires should be protected from electric interference by shielding braid (sleeving) made of thin tinned copper wires. The braiding comes in different diameters from 2 × 4 to 40 × 55 mm. The gauge of wires used for the braiding is dependent on the diameter of the braid. The double notation of the braiding diameters indicates the minimum and maximum internal diameters formed respectively during stretching and compressing the sleeve. In high-frequency cables such braiding from wire gauge 0.15 to 0.3 mm is used as the coaxial-line outer conductor.

Bare wire. Interconnections are sometimes made with the use of bare round-section copper wire; soft annealed wire brand MM from 0.31 to 1.62 mm in diameter is commonly used for this purpose. Sometimes soft copper wire is silver-plated to reduce electric losses, though tinned wires are used more often (hot-tinning method).

Insulated wires. A great variety of insulated wires are used for interconnections. The choice of a particular wire brand is governed by the operating conditions of the apparatus and the operating voltage. Simple single-conductor rubber-insulated connecting wires of the MP, MPГ, РПОЭ, МРГП, МРГПЭ, and МРГЛ types are available.

Brand РПО and РПШ multiconductor rubber-insulated wires are also used for connections in radio equipment. The wire РПО has 10, 12 or 14 conductors from 0.35 to 2.5 mm² in cross section; it is rubber-insulated and additionally covered with aseptic cotton braiding. Shielded wire РПО may have, in addition, a screening braid of tinned copper wires. Cotton (and other fibrous) insulation is used in especially flexible cables.

In wiring radio equipment to be operated under sharp-changing climatic conditions requiring high dielectric strength, oil and gasoline resistance, use is made of wires (ЛПЛ-2, ЛПЛ-4, ЛПЛ-6, ЛПЛ-8) insulated with silk-varnished fabric The figure in the wire denomination stands for the number of insulation layers.

For fixed internal connections in small-size radio equipment operated at −60 to +50°C temperatures and relative humidity up to 98 per cent, polyvinylchloride-insulated wires are employed. Wires МГВСЛ are used for connections

in low-current radio equipment. Plastic-insulated connecting wires have high heat resistance.

Electric connections in radio equipment operating at —60 to +250°C at voltage up to 250 V within 50 to 500 c/s frequencies are made from heat-resistant wires with poly-fluoroethylene grade 4 film insulation. Under elevated temperature conditions connecting wires type БПТ and its screened version БПТЭ are also employed. Fixed connections in low-current radio equipment are made with film-insulated wires. Extensively used for electric connections are composite-insulated wires type МГШВ and МГШВЛ.

High-voltage wires. High-voltage wires are used in radio equipment connections designed for application in equipment operated below 33 kV, d.c., under various climatic conditions. They differ from other types of wires in high dielectric strength of the insulation.

Cables. Along with bare and insulated wires internal connections of radio equipment are also made with cables which are assemblies of electrical conductors insulated from each other. Twin wire cables with either parallel or twisted conductors and r.f. coaxial cables are employed in radio engineering.

Multiconductor cables in plastic insulation are used for fixed connections of radio equipment operating at up to 380 V at 50 c/s or 550 V d.c. They can withstand temperatures from —50 to +70°C at humidity up to 95 per cent. R. f. coaxial cables are used for connections in radio installations operating at —40 to +60°C and humidity up to 98 per cent.

21. Preparing Wires, Cables and Leads of Radio-Circuit Elements for Assembly

PREPARING CONNECTING WIRES

The method of preparing connecting wires for assembly depends on the rate of production and the wire brand.

Cutting connecting wires into lengths. Connecting wires (shielded wires as well) are cut into required lengths for assembly by means of special automatic machines, gate shears, electrician's scissors or nippers. The length of the

stock of wires, jumpers, cables and insulating tubing should conform to the sizes specified in the flow chart or stock table. It is prohibited to splice wires and cables from separate pieces.

In preparing the stock of wires by hand their lengths are either duplicated after patterns or measured. Lengthy connecting wires for inter-unit cables are cut on a special

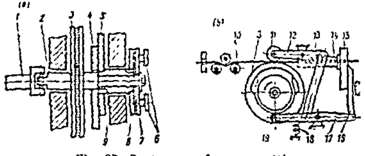


Fig. 88. Contrivance for wire cutting
a—clamping device, b—general view

device which measures off the required length automatically, or are cut by hand, pulling out the wire to a required length measured beforehand.

Cutting connecting wires in polyvinylchloride insulation into 30 to 200 mm lengths is advantageously achieved with the use of a special contrivance. It is installed on a lathe bed and driven from the spindle. The contrivance can be easily mounted and removed. Its efficiency depends on the spindle speed (one length of wire is cut off per one revolution of the spindle). A spindle speed of 120 rpm is the most convenient.

The contrivance operates as follows. Tail piece *1* which rotates shaft *2* through a hinged coupling is clamped in a three-jaw chuck (Fig. 88*a*). Driving disk *3* with a semicircular rolled groove for drawing the wire, cam disk *4* and disk *7* with a dial for setting the length of wires cut, are tightly fitted onto the shaft. Turning out screws *6* enables bush *9*, with cam disk *5* and notched disk *8* pressed on it, to be freely fitted onto shaft *2*.

Roller *19* constantly pressed to the disks by spring *15* is mounted on the left-hand end of rocker *17* (Fig. 88*b*).

The rocker right-hand end is hinged to blade *16*. Lower rocker *17* via draw rod *13* is connected with upper rocker *12* which has rubber-rimmed pressure roller *11* on its left-hand end. Rollers *10* are provided for straightening the wire which is protected from bending by tube *14*.

Operation of the contrivance depends on the position of roller *19* (in fact, on two positions of the roller):

1. When roller *19* moves on the circumference of the disks within the smaller radius section, roller *11* pressing the wire to disk *3* threads it and feeds through the tube to plate *15*. At this instance blade *16* is in the extreme lower position.

2. When roller *19* passes over to the larger radius section of the disks, roller *11* withdraws from disk *3*. The blade cuts off a length of wire and remains in the extreme top position.

The length of the wire cut is determined by the dial of disk *7*, and is controlled by turning disk *8* after releasing screws *6*.

Stripping wire of insulation. The insulation from the ends of connecting wires is removed on a section from 7 to 10 mm long if not otherwise specified in the flow chart. The wire of current-carrying conductors can be cut or damaged, if the insulation is stripped off with the use of knives or lancets, therefore this operation should be made on either automatic strippers or with the help of special devices.

The method of insulation stripping depends on the wire type. Types with plastic or polyvinyl insulation of the conductors are stripped on automatic machines simultaneously with cutting into lengths. The actuating mechanisms of these automatic machines are controlled with the aid of a cam whose contour represents three similar curves.

One cycle of operation is provided by turning the cam through 120°. Thus three measured lengths of wire are produced per one complete revolution of the cam (Fig. 89). The wire is fed in the required lengths automatically. Two pairs of rotating blades cut the insulation to a preset depth from both ends of the wire sheared off.

The mechanisms of the machine operate as follows. Unwinding from bobbin *9* (Fig. 90) the wire passes through brakes *10* and *11* and next through straightening rollers *12*.

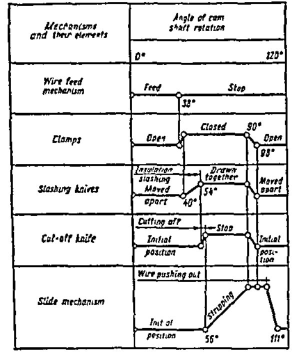


Fig. 89. Cyclogram of operation of automatic machine for cutting and stripping wires (automatic stripper)

Disk *7* and spring-mounted roller *8* feed the wire to clamps 6 and 24. Cam *1* controls the clamps with the use of rests *17* and *21*. Clutch *15* intermittently driven *from cam 1 turns* the feed disk. Wire feed is adjusted by handle *13* and is read out on dial *14*.

Upon fixing the wire by the clamps, two pairs of blades *3* and *4*, secured on the turning head and driven by gear wheels *2* and *5*, cut the insulation through to the current-carrying conductor. Blade *20* with a reciprocating motion from cam *1* through link *19* cuts off the wire. The number of wire stocks obtained is registered by counter *18*. When frames *23* and *22* shift, blades *3* and *4* strip the insulation from the wire between blades *3-20* and *4-20*, respectively. Further movement of the lower frame causes stop *16* to

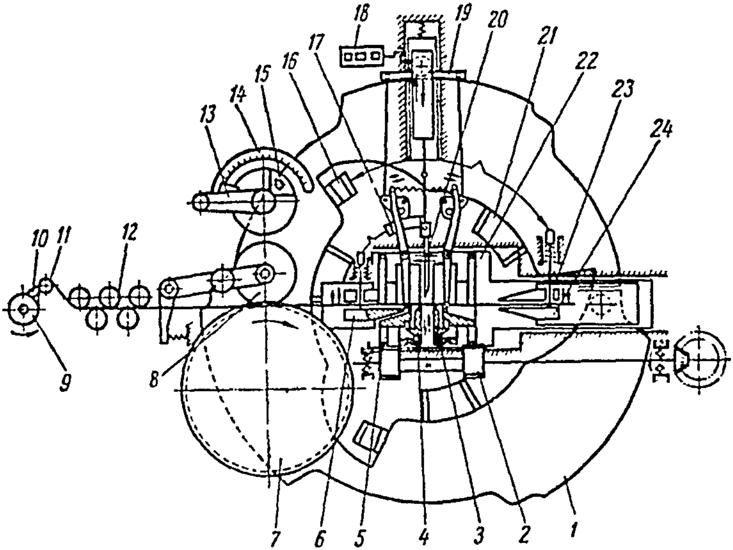


Fig. 90. Head of automatic stripper

release clamp *24* and the finished length of wire is pushed out into the receiving chute.

Automatic Machine Characteristics	
Length of wire cut, mm	50-800
Length of stripped section of wire, mm . .	15-70
Wire diameter, mm	0.1-1.5
Cycle duration, sec	3
Capacity per hr, pcs	1,200

Wires МГВ, МГВЛ, МГВСЛ, БПВЛ, ПВЛ, ПМВ can also be stripped of insulation with the help of a foot-operated device (Fig. 91).

Stripping of wire types МГВ, МГВЛ, БПВЛ, ПМВ, ПМОВ, ПМВГ, МГШВ, МПЛ, МОГ is achieved by electrical stripping with the use of closed-type device with a solenoid drive (Fig. 92*a*) installed in the preparing sector of a shop; or with electric pincers which remove insulation rom individual conductors (Fig. 92*b*).

In the electrical stripper (Fig. 92*a*) the wire end is introduced into hole *2* till it rests on a stop. The length of wire to be stripped of insulation is adjusted with screw *4*. Solenoid *1* controlled by foot pedal *6* draws together incandescent filaments which are supplied with 0.5 V current from transformer *5*. The wire is stripped in a cavity ventilated through hole *3* to which an exhaust hose is connected.

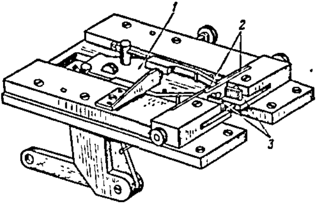


Fig. 91. Foot-operated stripper
1—slide; *2*—knives; *3*—holders

From individual wire types МГВ, МГВЛ, МГВСЛ, БПВЛ, БПТ, ПБЛ, ПМВ, МЦСЛ, ЛПЛ, МОГ, ТМ-200 insulation is removed with the use of special pincers (Fig. 93). Wire with combined insulation (МЦСЛ, ПМВГ, ЛПЛ, МГШВ, МОГ) is first stripped of the outer insulation layer on the automatic machine (see Fig. 90), following which the inner layer is removed in the electrical stripper. The outer layers of insulation of wires БПТ, ЦМСЛ, МТВСЛ, and ТМ-200 should not be electrically stripped, as they have glass-fibre and polyfluoroethylene braiding.

The operations of trimming and binding the insulation ends as well as fastening the braiding of wires intended for inter-unit connections are carried out after the wires have been tied into a bunch and the latter has been placed in a metal protective sheath.

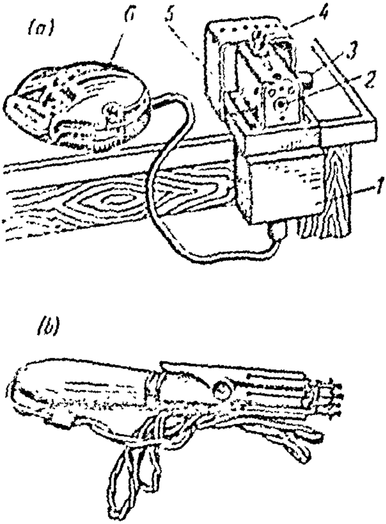


Fig. 92. Solenoid-operated jig (a) and pincers (b) for electrical stripping of insulation

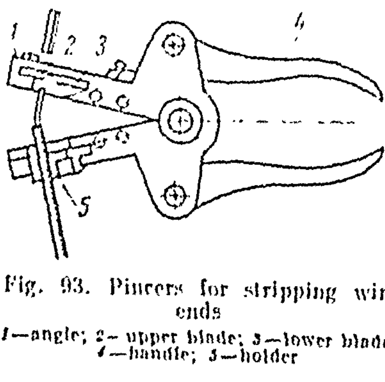


Fig. 93. Pincers for stripping wire ends

1—angle; 2—upper blade; 3—lower blade; 4—handle; 5—holder

Enamel insulation is removed by several methods: from wires ПЭТ and ПЭЛ by means of emery cloth or scraper; from wires ПЭВ and ПЭМ with the use of formic acid (dip the wire end into acid and rub with a soft cloth); from multi-conductor wires ЛЭШО and ЛЭШД by heating in the upper zone of a spirit lamp flame (heat the fluffy end of the wire to light-straw colour, quickly dip into alcohol and wipe with soft cloth).

Removing oxide film from current-carrying conductors. Current-carrying conductors of connecting wires, which have not been originally tinned (wires ЛШЛ, ЛПРГС and others), are cleaned of oxide film, using a device represented in Fig. 94. The end of the wire (with stripped insulation) is introduced through hole *1* in the casing (take care not to damage the insulation) in between rotating steel wire brushes *2*. After removal of the oxide film, the wire conductors are twisted together either with a special device or manually.

Fastening insulation ends. Methods of fastening insulation ends depend on the type of wire used. The ends of wire with cotton braiding are usually fastened with nitro-glue or by placing lengths of polyvinylchloride or linoxyn tubing on them to avoid possible fluffing and sliding. Nitro-glue

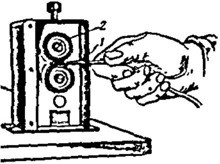


Fig. 94. Gear for removal of oxide film from connecting wire strands

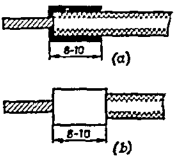


Fig. 95. Fastening of wire insulation with nitro-glue (a) and by pvc tubing (b)

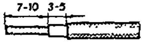


Fig. 96. Fastening cotton sheathing of БПВЛ, МГВЛ, МГВСЛ wires with nitro-glue

the polyvinylchloride insulation and its excess is spread out over the wire length (Fig. 96).

As a rare exception, textile braiding may be fastened by binding with cotton threads (Fig. 97), this method is extremely labour-consuming. Insulation *1* is bound with thread *2* on a section 5 to 7 mm long.

Tinning of stripped wire ends. The hot method is used for tinning stripped conductors on a section 5 to 8 mm long by dipping them for 1-2 sec into a bath with electrically

melted solder. To remove excessive solder, the wire is shaken, then wiped with a soft cloth. Prior to tinning the individual conductors are twisted together in a clockwise direction.

The ends of several wires can be tinned simultaneously (before that they should be levelled by slightly tapping them against the table surface). The wires are immersed

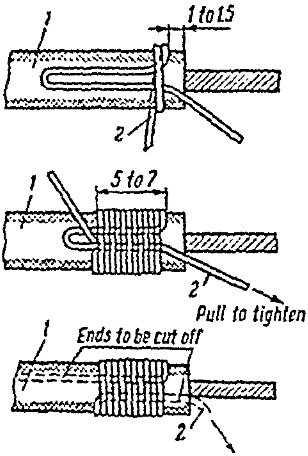


Fig. 97. Fastening of wire insulation with thread

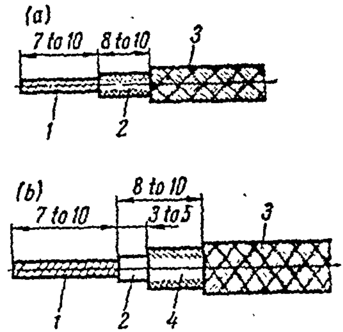


Fig. 98. Fanning out the end of a shielded wire

a—after fastening the braid shield; *b*—cotton sheath stripped off

into the bath, being held vertically. The wire ends are tinned with the use of acid-free fluxes. The ends of individual conductors are tinned with the aid of an electric soldering iron.

Fastening the ends of braided sheathing. If the braided sheathing might come into incidental contact with tags of a unit or component, it should be enclosed into a polyvinylchloride tube which is put on prior to fastening the ends of the braided sheathing. The sheathing is fastened so as to make its connection to the apparatus casing possible. This operation is performed as follows.

Remove the ends of insulation *2* of wires with conductor *1* and bind them after fastening braided sheathing *3*

(Fig. 98*a*). The ends of cotton braiding *4* of sheathed wire types БПВЛЭ, МГВЛЭ and МГВСЛЭ are cut off with scissors at 3-5 mm from the point of cut of the pvc insulation (Fig. 98*b*). The braided shielding of the wires is removed with scissors. Shift the ends of the braid, make a 20 mm cut along the wire starting from the edge and trim the

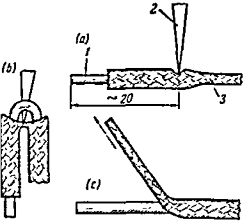


Fig. 99. Methods of fastening the ends of braid shielding
a—end of braid shielding pulled back; *b*—end of braid shielding drawn out; *c*—end of braid shielding stretched

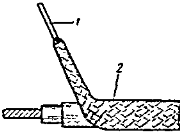


Fig. 100. Extension of grounding terminal of braid shielding

braid around to get rid of sticking out wires. Soldering on the shielding should be made with care not to damage the insulation. It should not take up more than 5 sec.

To fasten the ends of braid shielding of wires, following methods are suggested.

(1) By passing the wire through a hole in the braid and pulling out the free end of the braid (for wires МГВЭ only this method of fastening the braid is applicable). First of all the end of the braiding should be expanded (shifted back) as shown in Fig. 99*a*. The hole in the braiding is made at a distance about 20 mm from the end of wire *1* so that after stripping the insulation the braiding end is 8 to 10 mm from the uncovered conductor. The free end of the braiding is gently pulled out using pole *2* and is tightly pressed to the insulation at the point of wire emergence

(Fig. 99*b* and *c*). In this method of fastening, braiding *3* is equal in length to the wire and does not require additional trimming and binding.

The free end of the braiding is subsequently connected to the grounding lug. If the length of the free braiding end is not sufficient, a length of bare wire MM 0.5 to 0.8 mm in diameter (Fig. 100) is soldered to it. The end of the bare wire (4-6 mm long) is introduced inside the braiding *2*

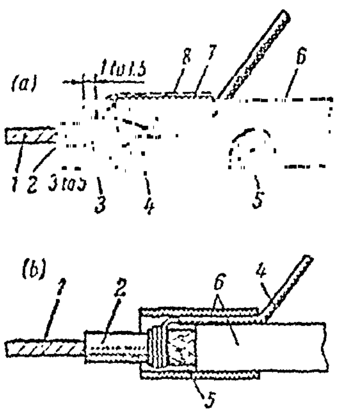


Fig. 101. Fastening a grounding wire to braid shielding end
a—multistrand grounding wire; *b*—single-strand grounding wire

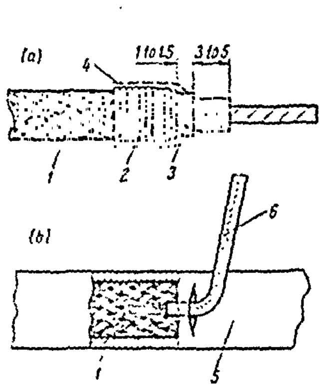


Fig. 102.
a—fastening of braid shielding end; *b*—soldering a wire to the braid shielding

from the butt. The end of braiding *2* and the soldered length of wire *1* are fitted with a linoxyn or polyvinylchloride insulating tube.

(2) Make a wedge-shaped cut in the edge of polyvinylchloride tube *6* (Fig. 101*a*) placed on braiding *5*, and using solder, secure the fanned-out end of wire *4* (type МГВ), 40-50 mm in length and 0.35 mm² in cross section, to the braiding at this point. Fasten with thread *7* and coat with nitrocellulose glue *8* the area of soldering and the end of the braid shield with the pulled-off end of the cotton sheath *3* (inside the sheath is conductor *1* with insulation *2*).

(3) Tightly wind 2 or 3 turns of bare tinned wire type MM 0.5 mm in diameter around the end of braiding *5*

(Fig. 101*b*) working away from the middle of the wire. One end of the bare tinned wire will remain free (40-50 mm long); the other end (after cutting off the excessive length) should be pressed with fitter's pliers to the sheathing. Following that solder the wire turns and the braid shielding end with the use of solder ПОК-56 (melting point 124°C). If solder ПОС-40 or ПОС-61 is used, place cable paper or varnished fabric between the cotton and shielding in the soldering area. Strip off the insulation, make the cotton sheath fast with nitrocellulose glue and put a linoxyn tube *6* (30 to 40 mm long and 0.5 to 0.8 mm in diameter) on the free end of the bare wire; cover the soldered area with a tight-fitting insulating tube 15 to 20 mm long.

(4) Using thread *2* fasten the ends of braid shielding *1* of the short wires (Fig. 102*a*) together with the cut-off end of cotton sheathing *3* and cover with nitrocellulose glue *4*. Solder the fanned-out end of wire *6* (type МГВ, 0.35 mm^2 in cross section and 40 to 50 mm long) to the middle of the braid shielding (see Fig. 102*b*). Put polyvinylchloride tube *5* on the shielded wire. Pass the free end of the soldered-on wire through a cross cut (4 to 5 mm long) made beforehand in the middle of the tube and pull the wire out.

CABLE PREPARING

Radio-frequency cables (PK) are cut to measured lengths by means of guillotine-type shears. The required lengths of cable are either measured with a graduated rule or with the use of a cable sample. The insulation and braid shielding are removed from the ends of cables in steps on a semiautomatic machine or with electrician's shears and electric knife. In doing so, care should be taken not to damage the conductors, the internal insulation and the braid shielding.

The ends of the cotton sheath of cables PK-44 and PK-45 are fastened with thread and coated with nitrocellulose glue. The oxide film from the bare ends of the conductors of cables PK should be cleaned off with a scraper or emery cloth of medium grain size. The cleaned conductor is tinned over a length of 5 to 7 mm with ПОС-40 solder.

The ends of the braid shielding of cables PK are tinned with solder ПОК-56 (if required) using a soldering iron. If ПОС-40 or ПОС-61 solder is used for this purpose, enlarge the diameter of the braid shielding end by pushing it back when soldering it to the connector (placing cable paper, electric insulating cardboard between the cable internal insulation and the screen sheath or fitting on a linoxyn tube).

PREPARING LEADS OF RADIO COMPONENTS

The leads of hook-up radio components (capacitors, resistors, etc.) prior to assembly should be straightened and shortened to the required length. The strip-type leads

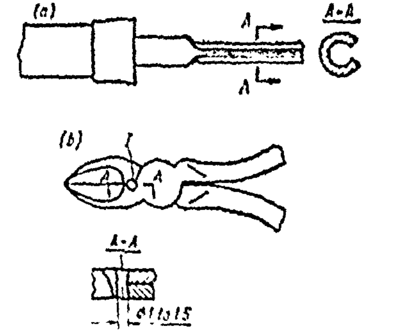


Fig. 103. Bending of a strip lead of radio component (*a*) and nippers or this purpose (*b*)

1—hole for constriction of band leads into a cylinder

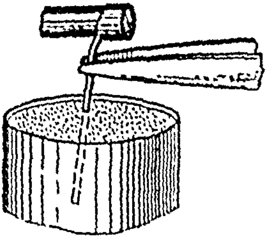


Fig. 104. Tinning resistor lead in a bath

of radio parts should be pinched to tubular cross section (Fig. 103*a*) or narrowed by an oblong cut for convenience of attachment to contact tags. The leads are pinched with pliers with a hole drilled especially for this purpose, as shown in Fig. 103*b*.

Oxide film and paint are removed from the leads of radio components with a scraper or emery cloth. The cleaned leads should be tinned with ПОС-40 solder at a distance of 8 mm from the component. If it is necessary to apply the tin more close to the component, use is made of pincers

with heat-sinking copper endpieces (Fig. 104). To conform with a model, the leads of radio components are bent using a templet (Fig. 105*a*) or with round-nose pliers (Fig. 105*b*) at not less than 2 mm distance from the component. The

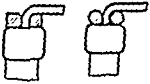


Fig. 105. Bending of radio component leads
a—in a templet; *b*—with round-nose pliers

bending radius should be not less than the double diameter (or thickness) of the lead. Sharp bends of leads or bends at the level of the component body should be avoided.

22. Preparing Bunched Conductors

Connecting wires that run in one direction are tied up into a common bunch, using cotton or linen thread. The thread should be preliminarily waxed.

Marking electric wires for bunches. The ends of wires in bunched conductors are usually marked by one of the following methods:

colour-coding of wire insulation;

painting or numbering the polyvinylchloride tubes used for fastening the insulation ends. The tubes are marked with numerals on an automatic machine, in special stamps or manually with marking ink;

gluing coloured or numbered polyvinylchloride adhesive tape, wrapping it round the wire ends 1.5 to 2 turns;

marking with multicolour nitrocellulose varnishes;

use of replaceable tags put on the wire ends when binding up the bunch and removed after the wires have been soldered to their appropriate contacts;

gluing numbered paper tags to the insulation ends. The tags are glued with БФ-6 cement and coated with colourless cellulose nitrate varnish.

Preparing bunched conductors (bunches) and their drawings (sketches). Bunched conductors and their drawings are prepared in the process of designing an apparatus or when preparing for batch production. In batch production the bunches are made with the aid of templets.

To prepare the bunch proceed as follows:

Carefully lay the wires to be made into a bunch on the chassis; the wires are laid in accordance with the wiring diagram and the table of wiring connections. The ends of wires to be attached to contact tags should not be specially cleaned. If colour-coded, the wire ends connected to the same contact tags should be marked in the same colour.

The bunched conductors should not contact with fasteners (nuts, screws, clips) and obstruct access to them, and that the wire insulation does not touch the contact tags of adjacent components. Wire insulation should be protected from damage in the holes of the shields as well as from stiffening ribs and other sharp projections with the help of polyvinylchloride tubes, pads or rubber sleeves.

The wires are laid starting with the shorter lengths and ending with the longer ones so that the latter form the bunch faceside. Screened wires not enclosed in a polyvinylchloride tube over their entire length should be placed in the bunch centre. If spare wires are specified in the bunched conductors, these should be of maximum length and placed on top of the bunch. The cross-sectional area of these wires generally equals that of the thickest wire in the bunch. Spare wires should be of a different colour-coding; wires of the same colour should not be placed together.

In laying each wire measure its length; this is conveniently done after securing the other end. When cutting wire to a required length leave 20 to 25 mm extra for fastening the ends, and the same length (20-25 mm) for repeated connection in case of snapping. Enter these results into the table of wiring connections.

An example of binding a bunched conductor with branching wires is illustrated in Fig. 106. Wires *1* are made into a neat bunch *2* and tied up with strong cotton thread *3*, using a bent needle. The loops are tightened up at equal spacing (not over 25 mm) and also in the points of wire

branching (Fig. 106a). The thread ends are fastened as in Fig. 106b. In joining threads, their ends should be tied up (Fig. 106c).

The internal radius of a bend in a bunched conductor should be no less than double the external diameter of the thickest wire in the bunch.

Upon completing the bunch in the apparatus, detach the wire ends from the contact tags of the components, take the

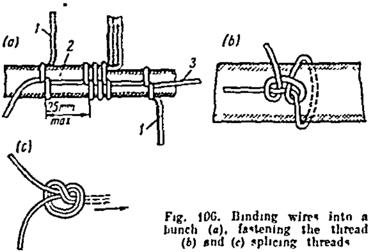


Fig. 106. Binding wires into a bunch (a), fastening the thread (b) and (c) splicing threads

bunched conductor out and straighten on a level surface, shaping the bunch as required. If the assembly wires are arranged in various planes, they should be bent at 90° into the plane of the major part of the bunch so as to twist the wires instead of bending. The branches should be bent towards the bearing wall or panel (Fig. 107).

On straightening the bunch, place it on a sheet of drafting paper with the face down (i.e. in a position opposite to that it will occupy in the apparatus) and carefully trace the branching wires. The outlet points and directions of wires, their length and end markings are designated as shown in Fig. 108.

The sketch of a bunch thus obtained should be corrected with the help of a rule. Group the ends of the bunch wires in such a way as to use as few pins on the forming board

as possible. For this purpose it is practicable to slightly change the outlet points of some wires (with a corresponding change in their lengths). The sketch is used to make a forming board and in preparing the operational flow chart for the bunch.

Strictly following the sketch, lay out and make a pilot forming board (templet) which should be of the simplest design possible (a sheet of plywood with the bunched conductors plotted on it and with pins located where required—

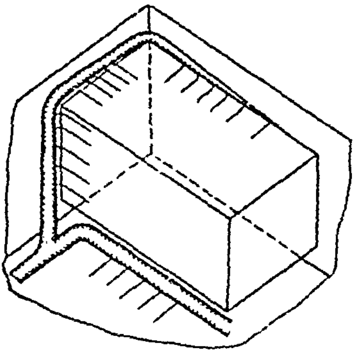


Fig. 107. Method of branching bunched conductors in one plane

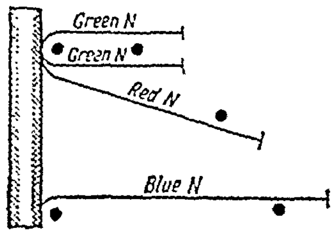


Fig. 108. Designation of bunched conductors and branch wires on a sketch and forming board (bold dots mark pins on the forming board)

Fig. 109). Lay out and tie up the first (experimental) bunch on the templet. Cut off the wire ends at the end crosswise marks (see Fig. 108), mark them and make fast, twisting them around the pins (one turn).

The wires are arranged on the forming board in a sequence opposite to that stated above, i.e. starting with the spare and long wires and finishing with the shortest lengths. Such an order is necessary to make the wires look more neat; now all the thread knots on the bunch will not be in view after the bunched conductors are fitted and wired in the apparatus.

Following that, place the experimental bunch on the apparatus chassis and check for correct configuration, position of branching outlets, and branch lengths. In doing

so, correct all minor inaccuracies (practically almost unavoidable) and introduce necessary amendments into the bunch sketch and table of wiring connections. The actual forming board is made in accordance with the corrected sketch.

In preparing bunched conductors we recommend to use forming boards with clips instead of pins and a light signal system for indicating the points of connection of the other ends of the wires and, if necessary, the direction of wire laying. In using such forming boards errors in arranging the wires will be eliminated and no additional technical documentation is required.

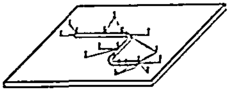


Fig. 109. Forming board for bunched conductors

Laying out and binding inter-unit wires (bunched conductors). In this operation all the above rules should be followed. No interlacement of wires is permissible except cases otherwise specified in the flow chart. Wire crossings are permissible only at points of emergence from the bunch and in case of crosswise position of the branches.

For laying out bunched conductors stocks of wires with cleaned and trimmed ends are used. In laying and binding wires care must be exercised not to damage wire insulation and not to crack the bare ends. Bunched conductors are bound with the aid of a metal shuttle (*Fig. 110*) *using thread* wound beforehand, or with a bent needle.

When fitting the bunched conductors in the apparatus, the ends of the wires should be carefully spread out with pincers in the directions of the contact tags to which they should be connected. Particular care not to damage the trimmed insulation ends and the marking should be taken when passing branches of the bunch and individual wires through rubber sleeves.

Sections of bunched conductors less than 150 mm in *length are reliably held in place by the branched wires* connected to contact tags of the components. Sections of bunched conductors *1* void of branches and longer than

as possible. For this purpose it is practicable to slightly change the outlet points of some wires (with a corresponding change in their lengths). The sketch is used to make a forming board and in preparing the operational flow chart for the bunch.

Strictly following the sketch, lay out and make a pilot forming board (templet) which should be of the simplest design possible (a sheet of plywood with the bunched conductors plotted on it and with pins located where required—

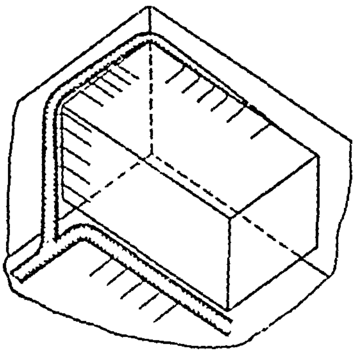


Fig. 107. Method of branching bunched conductors in one plane

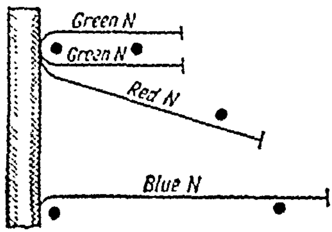


Fig. 108. Designation of bunched conductors and branch wires on a sketch and forming board (bold dots mark pins on the forming board)

Fig. 109). Lay out and tie up the first (experimental) bunch on the templet. Cut off the wire ends at the end crosswise marks (see Fig. 108), mark them and make fast, twisting them around the pins (one turn).

The wires are arranged on the forming board in a sequence opposite to that stated above, i.e. starting with the spare and long wires and finishing with the shortest lengths. Such an order is necessary to make the wires look more neat; now all the thread knots on the bunch will not be in view after the bunched conductors are fitted and wired in the apparatus.

Following that, place the experimental bunch on the apparatus chassis and check for correct configuration, position of branching outlets, and branch lengths. In doing

so, correct all minor inaccuracies (practically almost unavoidable) and introduce necessary amendments into the bunch sketch and table of wiring connections. The actual forming board is made in accordance with the corrected sketch.

In preparing bunched conductors we recommend to use forming boards with clips instead of pins and a light signal system for indicating the points of connection of the other ends of the wires and, if necessary, the direction of wire laying. In using such forming boards errors in arranging the wires will be eliminated and no additional technical documentation is required.

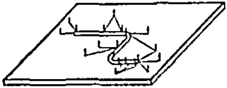


Fig. 109. Forming board for bunched conductors

Laying out and binding inter-unit wires (bunched conductors). In this operation all the above rules should be followed. No interlacement of wires is permissible except cases otherwise specified in the flow chart. Wire crossings are permissible only at points of emergence from the bunch and in case of crosswise position of the branches.

For laying out bunched conductors stocks of wires with cleaned and trimmed ends are used. In laying and binding wires care must be exercised not to damage wire insulation and not to crack the bare ends. Bunched conductors are bound with the aid of a metal shuttle (Fig. 110) using thread wound beforehand, or with a bent needle

When fitting the bunched conductors in the apparatus, the ends of the wires should be carefully spread out with pincers in the directions of the contact tags to which they should be connected. Particular care not to damage the trimmed insulation ends and the marking should be taken when passing branches of the bunch and individual wires through rubber sleeves.

Sections of bunched conductors less than 150 mm in length are reliably held in place by the branched wires connected to contact tags of the components. Sections of bunched conductors *1* void of branches and longer than

150 mm, as well as coaxial cables PK, are fastened to chassis *2* with metal clips *4* bent to fit the bunch or cable section (Fig. 111). At the point of fastening the bunched conductors are wrapped with pad *3* (electric insulating cardboard or

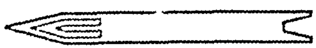


Fig. 110. Shuttle for binding bunched conductors

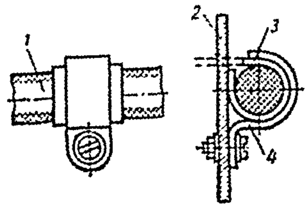


Fig. 111. Fastening of bunched conductors to chassis

pvc) which is 3 to 5 mm wider than the clip and no less than 0.5 mm in thickness.

Laying and binding inter-unit bunched conductors. These should be laid and bound preserving the mutual arrangement

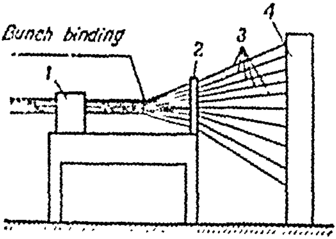


Fig. 112. Binding bunched conductors of inter-unit cables with the aid of a fixed comb gadget

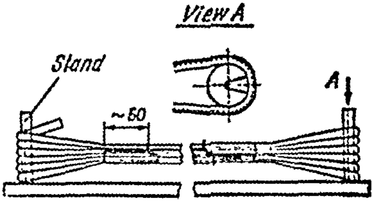


Fig. 113. An example of fabricating bunched conductors of inter-unit cables

of wires over their entire length. For this purpose use is made of a fixed comb *2* (Fig. 112) which is a metal plate with holes in number and arrangement corresponding to the number and position of contact lugs in the largest connector. Wires *3* unwound from stand *4* and passed through the holes in the comb are bound into a bunch as they are drawn through the fixed comb, or as the comb is withdrawn from the fixed wire ends. Following that, wires *3* bound into a bunch are cut off by means of a shearing device *1*.

In laying and binding inter-unit bunched conductors (Fig. 113) the constance of the mutual position of wires is achieved by tightly stretching out the wires during winding on stands, identical arrangement of turns on both stands, and by proper binding. The method illustrated in Fig. 113 is applicable for binding bunched conductors comprising wires of the same brand and gauge and taken from one coil.

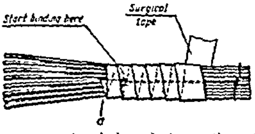


Fig. 114. Wrapping bunched conductors with surgical tape

The bunches are bound with linen waxed thread by means of a shuttle (see Fig. 110). Loops are evenly spaced at approximately 50 mm.

Multicore cables in masticated covering grade KMB consisting of wires МГШВ in multicolour insulation are used for inter-unit bunched conductors with less than 14 wires.

The ends of inter-unit bunched conductors are sometimes wound with surgical (herringbone) tape. The tape is wound tightly with an overlap of subsequent turns (Fig. 114). One end of the tape is passed between the wires to the opposite side of the bunch, drawn along the bunch until it rests against the thread binding, then bent towards the binding and placed under the first tape turn. The other end of the tape, on completing the winding, is cut off and fastened with linen thread. Following that the tape is impregnated with cement БФ-6.

Inter-unit bunched conductors are enclosed in protective metal-braided sleeving. Depending on the length of the bunch, this latter operation is either done manually, [illegible] the bunch through the sleeve or with the help of a [illegible] jig. In pushing the bunch by hand its end and [illegible] are wrapped with insulating tape or enclosed in [illegible]

sleeve of appropriate size (diameter) and tightly constricted around the bunch.

In drawing bunched conductors *4* through braiding *1* with the aid of a special jig consisting of metal rod *2* and

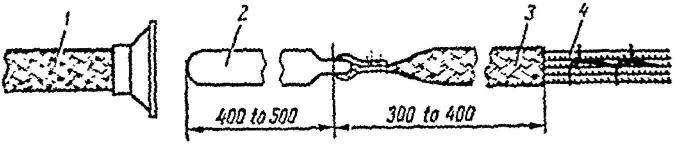


Fig. 115. Gadget for sheathing inter-unit cables

a length of braid *3* of appropriate size attached to it (Fig. 115); the braid should be preliminarily expanded, put on the bunch end and tightened there.

23. Fastening Wire Ends and Leads of Radio Elements to Contact Lugs

In assembling radio equipment the wire conductors and leads of hook-up radio parts before soldering should be mechanically fastened (Fig. 116*a* and *b*). The conductors

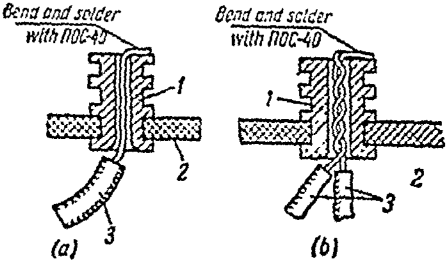


Fig. 116. Fitting cable conductors (wire strands) and leads of radio components in lugs

a—single wire; *b*—twisted wire

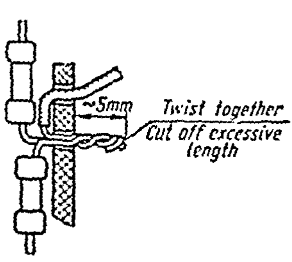


Fig. 117. Fastening wires and leads of radio components on panels without lugs

of wires *3* and the part leads are passed into the soldering hole of contact lug *1* in panel *2* and are bent aside or hooked round the lug by half-turn or complete turn with the help

of pincers or electrician's pliers. The excessive length of conductor or lead is cut off with cutting pliers. On panels without lugs wire conductors and leads of radio elements are secuerd as shown in Fig. 117.

Soldering of unfastened ends (butt or lap joints) is inadmissible. As an exception (specified in the flow chart), it is permitted to make a temporary soldered joint of the leads without mechanical fastening; this is permissible only for elements selected in the process of adjustment (marked with asterisk in circuits), and these must be mechanically fastened and soldered after final selection. To general-purpose and h.f. plugs and connectors wires are soldered without mechanical fastening.

The contact lugs of tube sockets prior to wiring are bent outside approximately by 45°. Before connecting wires to "floating" lugs of a bantam tube socket special templets are inserted into the tube socket to fix the lugs in position. Not more than three current-carrying strands should be attached to one lug. The connection of a greater number of wires (but not more than five) is permitted only in cases specially stipulated in diagrams and flow charts. Not more than two current conductors of total cross section not over 1 mm^2 should be attached to the contact lugs of glass-sealed leads.

The distance from the point of the conductor attachment to the insulation edge should be not more than 1-1.5 mm. Wires with damaged or repaired insulation (either with tape or varnish) should not be used. Neither should electric wires with outer rubber insulation be used in close proximity to silver-coated surfaces.

Connections between movable contacts are made with flexible electric wires fastened with connections between movable contacts are made with a sag in the wire to exclude stretching when the distance between them is maximum. The connecting wires must not lie on sharp edges of the chassis and the edges of holes; this precaution is necessary to prevent insulation damage. Generally, the wires have 20 to 25 mm reserve length to permit a repeated fastening of the ends in case of snapping. Connecting wires (except bare wire jumpers) must not be stretched. The bending radii of wires and cables should equal at least double wire dia ,r.

For protection of connecting wires against damage the ends of pincers used for bending and laying the wires are fitted with polyvinylchloride tubing.

The ends of wires are fastened with the markings facing outwards. Wires in a bunch are connected in accordance with the marking, colours and length. In case of any doubt as to correctness of the connection check the wires and find the right ends with the aid of a tester. The connections must be made only if no doubt in their correctness arise.

All the hook-up parts are first marked in compliance with their designation in the circuit diagram. Their leads are provided with insulating tubes. The distance from the points of fastening of the leads of hook-up elements to their bodies should be as short as practicable but not less than 8-10 mm if not specified otherwise in the flow chart.

The length of both leads of radio components after their fastening should be equal.

The assembled hook-up radio components should be spaced from each other, from the chassis and from other current-carrying surfaces by not less than 2 mm. If the parts are coated with moisture-resistant varnish, this distance may be reduced by a factor of two. In case of close arrangement of parts, insulating tubes should be fitted on. The contact lugs of precision and glassed resistors must not be bent in assembly.

The tinned cores of hook-up wire secured in cable lugs are fitted into the latter and tightly squeezed together with special forceps (round-nose pliers with grooves in the jaws to fit the cable terminal). After cutting off the surplus length of wire and soldering the joint, a polyvinylchloride tube is fitted onto the terminal. Not more than three wires with cable terminals should be clamped under one clamp contact. Multiconductor wires without cable terminals should not be used with clamp contacts.

25. Block Diagrams, Circuit and Wiring Diagrams

A radio apparatus is conventionally represented by drawings and diagrams.

The block or schematic diagram gives only a general idea of the radio apparatus, its principal units and their func-

tions. The block diagram consists of squares (blocks) or circles representing major units which sometimes incorporate several stages with electronic elements. The squares are provided with inscriptions explaining the purpose of each block or with conventional designations of components specific for the given unit. The squares are connected with lines showing the interaction of the blocks.

A typical block-diagram of a radio apparatus is represented in Fig. 118. The blocks which permanently take part

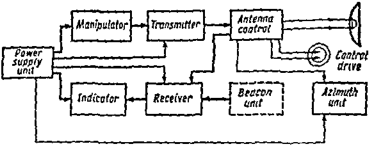


Fig. 118. Typical block-diagram of a radio apparatus

in operation and the permanent interconnections are plotted in solid lines; special-purpose units with intermittent duty and connections of a temporary nature are shown in broken lines. Mechanical connections between blocks are shown by double lines. Depending on the complexity of design and application, individual elements of the apparatus give name to the blocks of the diagram.

A circuit diagram shows the detailed interconnections of actual components in each stage and illustrates the principle of operation. The diagram is the initial data for designing the equipment and its electric wiring diagrams and for training purposes; in conjunction with the wiring diagrams it is also used in the process of assembly, adjustment and operation of the apparatus.

In the circuit diagram each element essential for the apparatus operation is represented by a particular symbol. Elements required in the apparatus either for the purpose of wiring or for design considerations (terminal blocks, plug-and-socket connections, etc.) are not usually illustrated

in the diagram. In these diagrams the details of wiring, such as grades and gauges of wires, number of terminals and terminal blocks pertaining to internal wiring, etc. are also avoided. In the diagram all the electric connections of the apparatus elements are shown by separate lines. All lines on a circuit diagram are bended at a 90° angle.

To simplify the circuit diagram, groups of separate lines are sometimes blended into common lines with the joints made in radii. The merging lines are given a particular number which is the same at both ends.

The conventional symbols of elements which are assigned a particular function in the apparatus are grouped in the diagram in one place irrespective of their actual location in the apparatus (as groups of synchronous transmission and reception drives, elements of amplifying, rectifying signalling devices). If required, these groups are separated from the rest of the circuit by outlining them with a dot-and-dash line and indicating their designation or symbol.

The component symbols in the groups and the groups themselves are arranged in the diagram in a way which provides easy and consecutive following the diagram and ensures a minimum number of intersections of the connecting lines.

The groups (blocks) are drawn in definite sizes (for instance, equal in height and differing in width) for the convenience of their positioning in rows and tracing lines between them, representing electric connections.

Elements in the diagram are represented in the following positions:

switches—in the OFF position;

change-over switches—either in the OFF or in a characteristic operating position;

relays, contactors, electric magnets in the "dead" (no-load) position;

contact devices—in the neutral position;

limiting devices—in a position corresponding to normal operation of the apparatus;

contacts which are closed and opened mechanically—in a position void of mechanical action;

rheostats and potentiometers—in characteristic positions under normal operating conditions of the apparatus.

If an element contains several windings represented by identical symbols (such as transformer windings), it should be made clear in the diagram which winding is connected in each particular case. This is done with the aid of inscriptions, giving the winding voltage rating; or by indicating the markings of the output terminals provided on the elements.

In certain cases waveforms and voltage values are indicated in specific points of radio apparatus.

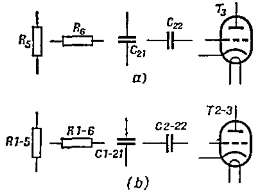


Fig 119. Conventional designation of elements on diagram
a—first method, b—second method

Controls and checking elements (change-over switches, instruments, pilot lamps, test sockets, adjustable resistors) are supplied with inscriptions, indicating their purpose or application in accordance with inscriptions provided on the apparatus outer walls.

The principal method of identifying elements in the diagram is to indicate them by letters accompanied with the element serial number placed after the letter symbol in the form of a numerical index (Fig. 119*a*).

For multiunit (multiblock) systems serial numbers are assigned to elements within a given unit (block), listing the unit number after the letter symbol and the serial number of the element in this unit after a dash (Fig. 119*b*), for example:

For unit 1:
R 1-1, *R* 1-2; *R* 1-3, etc
C 1-1, *C* 1-2, *C* 1-3, etc

For unit 2:
R 2-1; R 2-2; R 2-3, etc.
C 2-1; C 2-2; C 2-3, etc.

The reference (position) designations of elements in the diagram are shown at their graphical representations, if possible, at the left side, or under the element symbol.

The ground or chassis lines are graphically led to a common line (zero potential or "ground" line). In complicated diagrams with large numbers of connecting lines the chassis or ground signs may be drawn adjacent to the symbols of individual elements. The tube filament circuits are depicted in full and in complicated circuits only, they may be cut short and provided with arrows and explanations as to their connections. Shielding of wires, elements, units, and apparatus is also shown in the diagram.

Lines representing the electric connections with elements beyond the apparatus for which the circuit diagram is made are cut short at the diagram margins and provided with frames in which information on external wiring of the unit is given. Each output terminal plate or plug-and-socket connector is provided with a separate frame bearing the reference designation.

In Fig. 120 a section of the circuit diagram of an ultra-high frequency (uhf) radio receiver is shown. The component symbols are provided with numbers. These numbers represent their symbols in a special table (list of components) in which the designation, type and ratings of the elements are given. An example of such a list is given in Table 7, in which some components of the circuit diagram (Fig. 120) are included.

The circuit diagram, however, does not provide information about the design features of many components, their layout on the chassis, the form and size of the chassis, etc. These gaps are filled in by pictorial or wiring diagrams which serve to help assemble the apparatus illustrated in the circuit diagram.

The wiring or connection diagram gives a complete account of the components which make up the apparatus and how they are actually interconnected. Whereas in the circuit diagram the connections between individual elements are traced without reference to the actual points of joining the

Table 7

Component List of UHF Receiver Circuit Diagram

Component No. on diagram	Application of element	Type	Rated value	Permissible deviation from the rated value, %	Operating voltage or power
16	Superregenerator tube	2Ж27	—	—	—
17	Audio frequency amplifier tube	2Ж27	—	—	—
18	Trimmer	—	2.8-4.5 pF	±10	1,000 V
19	Blocking capacitor of superregenerator tube screen grid circuit	КБГ-И	4,700 pF	±20	200 V
20	Self-bias resistor in superregenerator tube control grid	ВС-0.25	510,000 ohms	±5	0.25 W

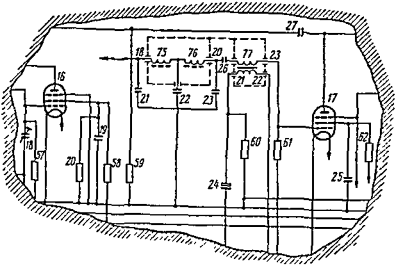


Fig. 120. Circuit diagram of uhf receiver (fragment)

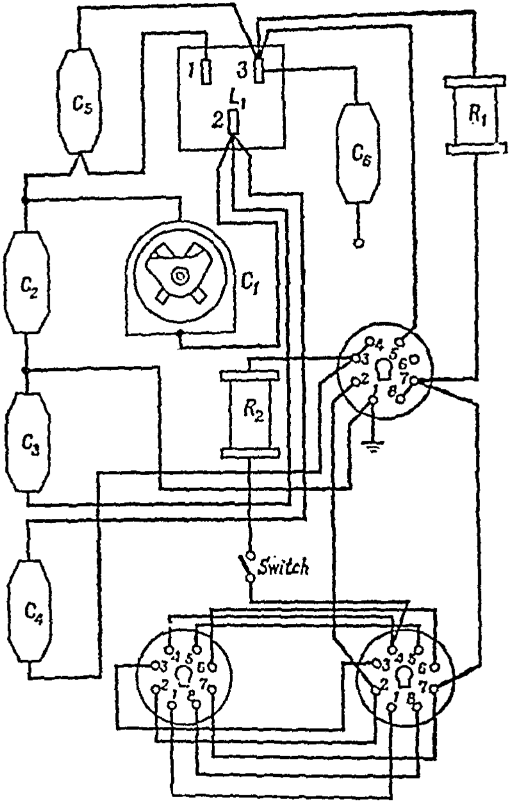


Fig. 121. Wiring diagram

hook-up wires; in the wiring diagram, on the other hand, all the connecting wires, terminal blocks and other points of connection are numbered and connected as they are wired in practice.

In the wiring diagram the basic data concerning the wires, cables, feeders, and bonding jumpers which connect the apparatus elements are listed. However the wiring diagram does not give the actual relative positioning of individual elements. It is a transitional stage between the circuit and the pictorial diagrams. A typical wiring diagram is represented in Fig. 121.

Pictorial diagrams are used as process charts for assembling radio equipment in batch and mass production. These diagrams are resorted to in the process of internal electrical wiring of the apparatus. Pictorial diagrams are drawn in accordance with the actual position of the elements and connecting wires, they contain all the necessary data concerning wiring. On this diagram the apparatus is shown from the side of wiring.

There are two methods of preparing pictorial diagrams: constructional and conventional.

In the constructional method all elements, connecting wires, cable strands, and cables are represented in simplified form. Such diagrams do not show the current paths in elements and are used together with the circuit diagrams. Constructional diagrams are resorted to when it is necessary to show exactly the mutual position of elements and connecting wires in the apparatus.

According to the conventional method, all radio elements, connecting wires, cable strands, and cables are reproduced by conventional symbols and lines. The diagrams made by this method illustrate the current paths in elements and can be used without reference to circuit diagrams. The conventional method is resorted to in cases when the representation of the mutual position of connecting wires and radio elements on the diagram is sufficient to ensure proper wiring of the apparatus.

If the operating conditions of the apparatus require the mutual position of connecting wires and elements to be definitely specified, a special wiring (design) drawing may be prepared either for the complete apparatus or for a certain part of it. This represents the constructional layout and fastening of connecting wires as well as the methods of fitting, sealing and attaching wire ends to element terminals. This drawing supplements the wiring diagram made by the conventional method.

Connecting wires in diagrams are designated by double serial numbers. The first number is assigned to each connecting line of the same potential; the second number—to each wire of the same electric line. For instance, 1-1; 1-2; 1-3, etc.; 2-1; 2-2; 2-3, etc. Figure 122 illustrates the designation of wires in electric diagrams. Wire numeration starts and [illegible]

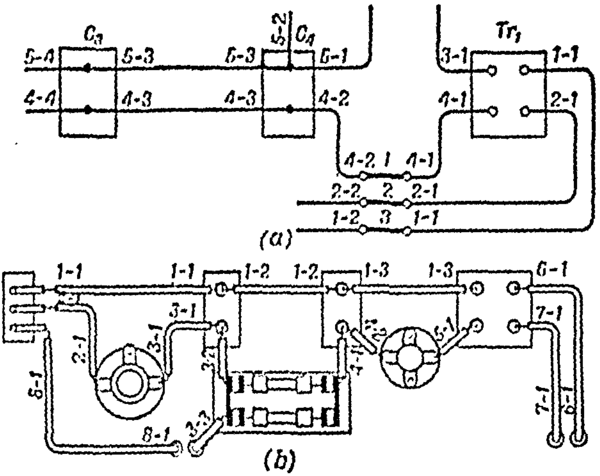


Fig. 122. Designation of wires in pictorial diagrams
(a) conventional method and (b) constructional method

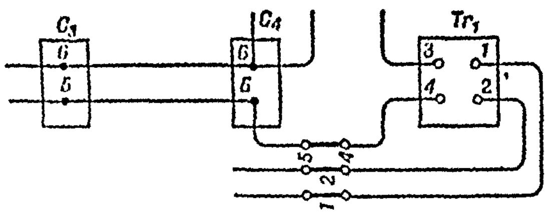


Fig. 123. Designation of wires, connected to one terminal, on wiring diagram

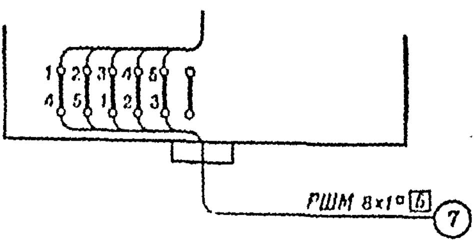


Fig. 124. Designation of a cable and cable conductors on a diagram (conventional method)

within one unit or apparatus circuit. The wire designation in the circuit is indicated at both wire ends. Short lengths of wire are sometimes marked at one end only and short jumpers (bare wire or plate) are not marked at all.

If each connecting line contains only one wire this is indicated solely by the line number. Wires connected to one terminal are specified in the diagram by similar numbers (Fig. 123).

Cable conductors are designated in wiring diagrams by single serial numbers within each cable starting with number one. The cables are assigned their respective numbers in compliance with the numeration on the general circuit diagram and in the diagram of connections in the following sequence: general-purpose cables, radio-frequency cables, other special-purpose cables.

The cable number is listed inside a circle located at the cable line end or is shown in marginal notes (for constructional diagrams). The cable grade, the number and gauge of conductors and the number of conductors used are indicated along the cable line adjacent to the number (in a square frame). An illustration of cable and cable conductor designation in a conventional wiring diagram is given in Fig. 124.

The table of the elements represented in the wiring diagram is located in the [illegible] [illegible] above the drawing title. The table is arranged in a form similar to that provided in the assembly drawing and is filled in from bottom to top.

of radio parts, preparation of stocks of bunched conductors, as well as the assembly of units and of the apparatus as a whole. After checking the stocks of connecting wires and cables visually, verify their brand, gauge, length, methods and quality of trimming and binding the ends, marking, absence of cuts in conductors and their tinning, absence of damaged and soiled insulation sections.

The dimensions are checked, comparing the stocks to models with the use of special gauges, rule or tape measures, and in certain cases estimating approximately by visual inspection. The type, rated value, marking, length, shape of bending and quality of tinning of the leads, absence of scratches, splits, cracks in the body and damaged inscriptions, sharp bends and fractures of the leads of hook-up elements prepared for assembly are checked by visual examination and comparison with models.

Wire layout is checked either with a tester or visually; also is checked the accuracy, tightness and correctness of binding of bunched conductors. The connections are checked for mechanical strength with pincers (fitted with pvc tubing), gently stretching the wire or lead.

In checking wiring joints make certain that the following conditions are observed:

all connections must be made with wires which have been mechanically fastened to contact lugs prior to soldering;

all soldered joints should be of the skeleton-type (the contour of the connecting wire should be seen under the solder), (slits and gaps between the connecting wires and lugs should be filled with solder), soldered joints should not have pores, bulges, beadings, and should have a lustrous surface without traces of flux;

the wire insulation and the insulation binding at the ends should be intact; pvc tubing on bare wire jumpers should not be fused;

glass beads on hermetically sealed components should have no cracks; connections of contact lugs with the output leads of such components should be in proper condition;

resistor leads should be secured to contact lugs without stretching (slightly sagging);

the wiring should be free of solder splashes, traces of flux, and scraps of wiring material;

the wiring should be properly fitted and neatly placed on the chassis;

the dummy bantam tube or its templet should easily fit into the tube socket after wiring the latter.

Correctness of assembly and wiring of jumpers, individual wires, hook-up radio components and marked bunched conductors is checked visually. If the marking is damaged, or absent, or there is any doubt of the correctness of the connections, check the wires with a tester. The assembled hook-up radio elements are checked visually and by comparing them with reference models; in specified cases they are checked with an ohmmeter or capacitance tester.

Inter-unit cables are checked for proper connection with the aid of a semiautomatic set-up or by connecting a tester to the plug-and-socket connector contacts having the same numbers. The units are checked for proper wiring with the aid of a semiautomatic set-up or by checking all circuits in turn with the help of an ohmmeter.

An essential requirement of all test operations is that they should be performed carefully, neatly and thoroughly to guarantee against any damage in the process of checking by tampering with the position of wiring elements, thus reducing the spacing between non-insulated elements or short-circuiting them.

Soldered joints of proper quality are marked by the inspector with coloured transparent cellulose-nitrate varnish which is applied to the soldered area with a special tube (of the drawing type) or with a soft brush. The soldered joints of hook-up elements which are matched during adjustment are marked with varnish only after a second check, which is done after the final adjustment and mechanical connection and resoldering of elements have been completed.

On checking the plug-and-socket connector contacts for proper soldering, the inspector slips the pvc tubes on the soldering points until they rest against the connector. If any defects are detected in the assembly and wiring, they should be recorded in the sheet of defects and the apparatus (unit) returned for correction to the foreman of the respective shop section.

Each batch of solder should be tested for chemical composition which should comply with the standard. The quality of each batch of flux is checked in the course of soldering. The flux should provide a uniform and strong connection of the solder with the basic metal; it should also be acid-free and contain no foreign inclusions. All components and units from other production shops are checked for quality of the surface preparation for soldering.

26. Safety Practices

The proper organization of labour, accuracy and care in the process of work are the essential conditions for the safety of the operator. Assembly operations require implicate adherence to basic safety rules.

Electric shocks present the most imminent danger. The operator must know that the effects of current on a human body depend on the current density, frequency, exposure time, current path and individual features of the human being.

The greater the current density, the greater the danger it presents (current from 0.1 A up, as a rule, is fatal). The greater the voltage, the less is the resistance of the skin and the greater is the danger of affection. Voltages below 40 V can be considered as relatively safe. Higher voltages, especially 220 and 380 V commonly used in industry, may be fatal.

The danger is increased with decrease in current frequency (the most dangerous for a human being are the industrial frequency currents) and increase of exposure time. This is due to the fact that the resistance of the skin, which to a certain extent protects a human being from current danger, reduces with prolonged exposure to the current. High-frequency currents (50 kc/s and higher), though not fatal, can cause heavy burns.

When pulling a plug out of a socket, grasp the plug and not the cord, since the latter can be torn out of the plug which might result in short-circuiting or inflict an electric shock. Faults in the mains should be repaired only by an electrician.

In working with microwave frequency installations the personnel can be subject to electromagnetic radiation from

various oscillators (magnetrons, klystrons, etc.). The most intensive electromagnetic radiation is from antennas, open ends of waveguides and the cathode leads of high-power oscillator tubes. Besides that the energy of electromagnetic waves can leak out of the joints between waveguide elements (flanges, boxes), through open flanges of waveguide directional couplers, cavity resonators, etc.

Systematic exposure to microwave electromagnetic radiation is damaging to a man's health. The extent of the influence depends on the duration and intensity of radiation. To avoid accidents and prevent adverse effects of microwave radiation, the following is essential:

thoroughly study the unit or apparatus circuit and locate all the elements which are under high voltage;

ground metal casings of the units of the apparatuses and measuring instruments;

check the power sources for proper operation and availability of the appropriate fuses and switches;

when working with high voltage place a rubber mat underfoot;

after switching off an apparatus, pulled out of its casing, discharge the capacitors with a special discharging rod;

microwave oscillators should be loaded to dummy loads (except in case of antenna measurements). The oscillators should be operated at a minimum power level sufficient for normal work;

check radio-frequency circuits for tight and reliable connections;

observe particular precautions in testing circuits for electric strength.

It is forbidden to:

check the presence of voltage and heating of the current-carrying elements of the circuit by touching them;

use wires with damaged insulation for the connection of units and devices of apparatus;

perform soldering and wiring operations in energized circuits;

measure voltages and currents with non-insulated jacks, rods, wires;

connect units and instruments to operating apparatus;

replace fuses on live apparatus;

work on high-voltage installations without special rubber gloves and insulated tools;

look into a waveguide open end at any power level;

repair any energized radio-frequency circuit;

tamper with the shields of microwave installations;

direct radio-frequency radiation beyond the assigned sector.

The operator's station should be free of unnecessary materials, tools and components, as this has an adverse effect on the productivity of labour and might cause a hand injury.

Liquids used for washing soldered joints (alcohol, solvent, turpentine) should be kept in well corked bottles. Evaporation should be reduced to a minimum; with this aim the bottles should be opened only when the liquid is used. To avoid fire danger, don't wash soldering joints with gasoline.

While working with a soldering iron guard your hands against burns especially with irons of 200 to 300 W used for soldering massive elements (screens, filters, transformers). Use a cloth folded several times for holding such parts during soldering. Support smaller components and bare wires during soldering with pincers or flat-nose pliers.

Particular precautions should be taken against splashing of solder in the process of soldering. This might happen when the soldering iron slips off a lead, the latter may spring back and spatter small particles of molten solder. In such cases the eyes must be protected first as the minute particles of molten solder may cause a serious eye injury.

Great care should be exercised during tinning ends of wires and leads in a molten tin bath. The bath should occupy a firm position on the bench and, prior to connecting it to the mains for melting the solder, it should be placed on a large tray made of sheet steel or brass with flanged edges 10 to 15 mm high. Such a tray will not let solder spill over the bench, if the bath accidentally turns over. The tray with the bath must not be carried about until the solder solidifies.

Cleaning wire insulation by scorching is accompanied by much smoke with disagreeable and heavy smell. For this reason a well ventilated exhaust hood should be used

when scorching many wires. If the wires are not in large numbers, their insulation should be scorched at an open window (in summer) or (in winter) the operator should either switch on an exhaust fan or thoroughly ventilate the room on completion of the operation.

In the course of soldering and washing of hot soldered places vapours of rosin, solvent and alcohol give off; particularly injurious to one's health are the vapours of tin and lead. They contaminate the air in a work room, which should be for this reason aired as frequently as required. This is usually achieved with the use of exhaust ventilation or (if lacking) by opening windows or air vents.

All tools should be reliable and handy for work, otherwise the operator will injure himself with the tools, if they are in bad repair. The wooden or plastic handles of screw drivers, hammers, hack saws should not be cracked. A handle with even a tiny crack can split in operation and the tool tang can cause heavy injury to the operator's hand.

In grinding drills and screw drivers on a grindstone guard the eyes against small particles of stone and metal, using either a protective glass mounted near the grindstone or protective goggles.

When drilling a hole in a drilling lathe take care not to hold the work by hand. The work should be clamped in a hand vice. Sometimes the drill can clinch in operation, especially when drilling thick stock; the drilled piece may be snatched out and the hands may be heavily injured if not removed in [illegible]

The operator's [illegible] chest so that first [illegible] sary.

CHAPTER FOUR

PRINTED CIRCUITS

27. General

The process of assembly, wiring and adjustment of a modern radio apparatus is very laborious. The total costs of these operations amount to 60-70 per cent of the entire cost of the complete apparatus. This can be explained by the fact that assembly, wiring, and adjustment operations are as yet insufficiently mechanized, and, in addition, involve skilled manual labour.

Wiring and adjustment operations of existing designs of radio equipment cannot be performed without manual labour. Progressive technological methods ensuring a rapid increase in output can be introduced only on the basis of a radical change in the design of the wiring circuits in the first place, as well as of individual components, units, and radio apparatus as a whole. Such new designs can be provided with the incorporation of printed circuits which enable the productional processes to be widely mechanized and automated.

Printed circuit elements are made in the form of thin layers of electric conducting materials deposited onto the surface of insulating plates.

This technology enables not only the wiring but the operations of assembly and soldering of radio devices to be mechanized and automated. Until recently these operations were generally performed manually.

The use of printed circuits reduces the time for assembly, wiring and adjustment operations and allows a sharp increase in the production rate of radio equipment; it also makes it possible to reduce the overall dimensions and weight, decrease the number of possible mistakes in assembly and thus the number of tests which are required in the conventional methods of production. Printed circuits encourage

further standardization of radio devices and their elements.

The revolution in electronic equipment manufacture due to the transition from metal chassis with a network of wires to structures consisting of panels with printed circuits has brought about a number of problems confronting the design engineers.

Prior to considering these problems, let us specify the terms used in the printed circuit engineering.

Printed conductor—a section of current-conducting coating deposited on an insulating base.

Printed element—a resistor, capacitor, inductor, conductor, etc. deposited on an insulating base in the form of a metallized or other coating.

Printed wiring—a printed circuit, or a portion thereof, intended primarily to provide electrical connection or shielding of circuit elements.

Printed circuit—a system of connections and some of the components printed on a common insulating base.

Printed circuit plate (board)—insulated base with printed wiring or printed circuitry.

Metallized hole—a hole in the printed plate with a layer of metal deposited on the hole walls; or a hole with a hollow rivet having electrical contact with the printed conductors.

Contact area—the metallized surface around a hole.

Wiring hole—a hole intended for securing the leads of a mounted (hook-up) element.

Mounted (hook-up) elements—electric and radio elements attached to the printed plate (board) by way of soldering and which are in electric contact with the printed conductors.

Printed unit—a printed plate with hook-up elements and parts.

Reference grid—a coordinate grid conventionaly superimposed on the printed plate drawing to determine the location of holes and dimensions of conductors.

Grid junction—point of intersection of two grid lines normal to each other.

Production conductor—auxiliary printed conductor providing electrical connection of individual conductors on the printed plate and subsequently removed.

Specific features of printed wiring. There is a number of features of printed wiring, including (1) the exclusively flat-type arrangement of printed conductors on a plate which does not permit the transition from one plate to another without jumpers, terminal blocks or connectors; (2) the use of same or similar devices in making printed circuit plates; (3) the introduction of a coordinate grid required for the mechanization of making holes in the plate.

In addition, printed circuits are characterized by the following peculiarities: mounting of hook-up elements and securing their leads exclusively by passing them through holes, simultaneous soldering of the leads of all elements assembled on the printed plate; definite succession in the assembly and wiring operations, viz: location of the hook-up elements on the printed circuit board and their preliminary mechanical fastening; soldering the leads of the hook-up elements; installation of other mechanically fastened components (racks, threaded bushes, etc.).

In all methods of producing printed circuit elements the current density for a printed circuit wiring is adopted equal to 20 A/mm^2; the adhesive strength not less than 25 to 30 kg/cm^2. Due to small weight and large surface of a printed conductor, its adhesive strength with the base is sufficient to withstand considerable alternating mechanical loads affecting the conductor during vibrations in a frequency range from 4 to 200 c/s.

Mechanical properties of printed conductors are adequate. In heating unequal linear expansion coefficients of the insulating base and the conductor material do not cause any complications as well as in case of current-conducting lines deposited on a flexible base. Since the plate is not porous or contaminated, discontinuities in the process of producing very thin conductors (as for coils) are ruled out.

Printed conductors are easily connected with structural elements by soldering and welding. The latter operation can be carried out without preliminary drilling or piercing holes between the current-conducting lines on both surfaces of the board.

Irrespective of the method of manufacture, printed conductors should meet the following requirements:

The conductivity of the deposited metal should approximate that of copper conductors.

The cross-sectional area of the conductor should correspond to the value of the current, as well as to the permissible voltage drop across individual portions of the conductor. The minimum width of the conductor is determined by the method of production and mechanical adhesion of the conductor with the base.

Irrespective of the thickness of the layer, length and shape of individual structural elements of the printed circuit a certain value of adhesive force between the deposited metal and base surface should be ensured in a temperature range of -60 to $+270$°C ($+270$°C is the maximum temperature of heating in case of mechanized production of the printed circuit).

Materials used for printed circuit boards. Depending on the technology of printed circuit production either a dielectric material is used on which the metallized circuit is deposited, or a dielectric covered with continuous metal layer (metallized dielectric) from which the excess metal is etched out.

In both cases the dielectric material should feature:

minimum dielectric permeability (not exceeding seven) to exclude considerable stray capacitances between printed conductors;

low dielectric loss tangent or dissipation factor in the operating frequency range which is of particular importance for high-resistance circuits; the loss tangent should not exceed 0.06 at 1 Mc/s;

specific surface and volume resistance of the insulation not less than 10^{10} ohm and 10^{10} ohm·cm, respectively;

dielectric strength not less than 15 kV/mm;

sufficient thermal stability to withstand the dip-soldering process at 240 to 270°C for 10 to 15 sec;

stable electrical parameters in the operating temperatures from -60 to $+120$°C. At a 30 ± 2°C temperature and humidity of 95 to 98 per cent sustained during 30 days the electric parameters should remain constant;

stable electrical, physical, chemical and mechanical properties in the process of production treatment;

sufficient mechanical strength and good machinability (in drilling, stamping, milling);

a homogeneous (in colour) surface void of impurities.

Printed circuit boards are usually manufactured from hard cardboard grades Ав and Бв. Its electrical properties are not very high, however it is easily machined, is cheap and ensures normal operation of circuits at frequencies up to 30 Mc/s. At frequencies above 5 Mc/s high-frequency grades of hard cardboard (Вв and Гв) are used.

Hard cardboard boards used for printed circuits should not be more than 2 mm thick to permit for their production by stamping. Hard cardboard from 3 to 4 mm thick is used in cases of heavy mechanical loads and usually for plates with more than 300-400 cm^2 area.

In addition, printed circuit plates are made from textolite (resin-impregnated laminated cloth) grade B4 and glass-fibre textolite grade Ст. Other electric insulation materials, such as ceramics, glass, molding powders, are also used.

The use of molding powder plastics encounters a number of difficulties, of which the principal is that it necessitates the manufacture of intricate molds which must be changed each time the design of the printed circuit plate is changed. The best molding powder for printed circuit boards is plastic type АГ-4. Polystyrene is unacceptable, if dip-soldering is specified, since its thermal stability is low, though it is very adequate for printed circuit plates operating at ultrahigh frequencies. The most promising is the polyfluoroethylene grade 4, though its use for printed circuit boards is restricted due to difficulties encountered in producing a strong joint when gluing it to metal.

DESIGN OF PRINTED CIRCUIT UNITS AND PLATES. RECOMMENDED METHODS OF MOUNTING OF HOOK-UP ELEMENTS

The principal advantage of printed circuits is that they can be manufactured using advanced processing technique which opens up wide possibilities for automation and mechanization of assembly and wiring; at the same time it requires technologically sound designs.

The technological requirements discussed below refer to printed circuits manufactured by electrochemical etching of metal foil.

Conductor width. The width of a printed conductor depends on the current density, permissible voltage drop, required mechanical strength and method of fabrication. A conductor with a less than required cross section is susceptible to overheating which may disrupt the connection of the conductor with the base or result in conductor rupture.

The data on the temperature of heating, cross-sectional dimensions and current are listed in Tables 8 and 9.

Table 8

Dependence of Temperature on Current Value and Cross-Sectional Area of Conductor

Conductor dimensions		Current (in A) resulting in heating conductor to	
Width, mm	Thickness, μ	60° C	100° C
0.5	10	5.2	5.8
1.0		5.6	6.5
1.5		6.5	7.6
0.5	20	6.0	7.0
1.0		7.0	8.2
1.0		8.0	10.0

Table 9

Recommended Current Values vs Printed Conductor Dimensions*

Width of conductor, mm	Current (A) with conductor thickness of	
	10 μ	20 μ
0.5	1.0	1.6
1.0	1.5	2.0
1.5	2.0	2.5
2.0	—	3.0

* At an ambient temperature of 20±5° C.

The maximum permissible currents in printed conductors, as seen from these tables, are higher than for round-shaped hook-up wires. Thus, a printed conductor 1 mm wide and 0.05 mm thick made from foil, due to good thermal conductivity and a relatively large surface, can be loaded with a 3 to 5 A current, whereas the standard current for a round-shaped conductor of the same area is but 0.5 A (for a rated current density of 10 A/mm²).

The electric resistance of printed conductors to d.c. is slightly higher than for round conductors due to irregular edges of the printed conductors and higher resistivity of copper foil and copper deposited by the electrochemical method. The resistance of a printed copper conductor 0.05 mm thick and 1 m long produced from foil is as follows (vs the conductor width):

Width, mm	0.5	1.0	2.0	3.0
Cross section, mm²	0.025	0.05	0.10	0.15
Resistance, ohm	1.0	0.5	0.25	0.18

The resistance of an electrically deposited copper conductor 1 mm wide and 1 m long depending on the thickness of copper built up is as follows:

Thickness, μ	10	20	30
Resistance, ohm	3.5	2.0	1.5

In designing printed conductors due consideration should be paid to voltage drop which might interfere with the normal operation of the circuit; therefore it should be primarily accounted for in designing filament circuits. For instance, a 6 A current can be passed through a foil conductor 1 mm wide having a 0.5 ohm/m resistance; the current will heat the conductor to 52°C. With a 200 mm length of the conductor voltage drop will amount to 0.5 V which can cause faulty operation of the tubes. These considerations prevent taking full advantage of one of the features of printed currents, namely, high current densities.

The minimum width of the conductor is dependent on the technique of their fabrication. One of the most advanced methods—offset printing with the use of bimetallic stereotype blocks—makes it possible to obtain foil conductors as narrow as 0.3 mm and electrochemically deposited copper

conductors 0.4 to 0.5 mm wide. However, a 1 mm width of conductors made by the offset printing method is economically expedient.

In using other types of stereotype blocks it is advisable to increase conductor width to 1.5 mm.

An increased width helps to obtain printed conductors with uniform edges.

Thickness of conductor. The thickness of a printed conductor depends on the thickness of the foil available. At present foils 0.05 mm thick are used in the USSR.

In electrochemical deposition it is impracticable to make a conductor thicker than 0.03 mm since a thicker conductor will require more time for its fabrication. In addition, the adhesion of a conductor to the base diminishes with an increase in its thickness. Thus a conductor 0.1 mm thick has so weak an adhesion that it is difficult to ensure sufficient mechanical strength of such a joint.

Spacings between printed conductors. Spacings between printed conductors obtained in different ways are chosen depending on the operating voltage (Table 10). The minimum spacing between the edges of conductors, as determined by technological considerations, should be 1.0-1.5 mm. The minimum spacing (though impracticable economically) is 0.3-0.4 mm.

Table 10

Minimum Spacing Between Conductors Printed on a Hard Cardboard Base as a Function of the Operating and Breakdown Voltages

Spacing between conductors, mm	Breakdown voltage, V	Operating voltage, V
0.5	1,000	250
1.0	1,500	400
2.0	2,200	600
3.0	3,000	750

The spacing between the soldering points in all cases should be not less than 1.5 mm which is sufficient to avoid short-circuiting of the adjoining conducting lines by the solder (dip-soldering).

Layout of printed conductors. Flat-type placement of conductors and component parts in printed circuits requires, as compared to hook-up wiring, a more careful layout of the insulating base. The conductors should be short, especially in grid and plate circuits, and should not have sharp changes from wide to narrow sections. The conductors should change direction gently so that the internal radius of curvature is not less than 2 mm.

Sharp changes of the direction and width of the conductor reduce adhesion of foil or deposited copper to hardened paper, which in subsequent machining of the plate or heating in the process of soldering might result in peeling the conductor off the base. For the same reason foil conductors should be located at not less than 1 mm from the edges and large holes in the plate.

In fabricating printed circuits by etching, it is desirable that the foil sections not used as conductors be left on the plate and connected between themselves and with the grounded parts of the device. However, circular arrangement of the foil around high-frequency units (such as inductance coils) should be avoided, since the short-circuited turn thus obtained will impair the parameters of the circuit.

To prevent the buckling of the foil and peeling it off the base due to gases liberated during heating the plate in the process of soldering, conductors wider than 5 mm should be provided with continuous slots or small sections of the foil should be etched off.

For economical and technological reasons (economy of foil, etching solutions and convenience of arrangement of the component parts) conductors obtained by the etching method should be arranged on one side of the plate. Intersections should be made with the help of wire jumpers or hook-up elements arranged on the free side of the plate. The wire jumpers inserted into specially provided holes are soldered to the printed conductors simultaneously with the leads of the hook-up elements by dipping them into molten solder.

If printed conductors are arranged on both sides of the plate, the current-carrying lines are passed from one side to the other by means of hollow rivets (pistons) or wire led through special holes in the plate. The rivets inserted

into the holes should be flanged out and the ends of the wire bent.

For reliable soldering it is desirable to tin the pistons and wires as well as the surfaces of the printed conductors in touch with each other, before soldering.

Fabrication of printed conductors on both sides of the plate and their passing from one side to the other do not present technological difficulties when electrochemical techniques are employed. The current-carrying conductors are passed from one side of the plate to the other by depositing metal on the walls of special holes simultaneously with building up the layer of conductors.

In fabricating printed circuits by electrolytic deposition of metal, it is essential that all conductors be interconnected; for this reason the circuit is provided with auxiliary temporary conductors which ensure current flow to all sections of the circuit without additional complicated means. Reduction of resistance and deposition of metal in a more uniform layer on all the circuit sections are promoted by making these temporary conductors as wide as possible. For the same reason additional temporary-type jumpers are joined at several points to conductors longer than 250 mm; after building up the conductors these jumpers are removed or ruptured.

Sometimes temporary conductors are removed by stamping; they are ruptured when punching holes. This operation can also be performed by drilling, reaming and trimming the ends of the board where the temporary conductors are led out.

In certain cases instead of temporary conductors use is made of a flexible contact in the form of a sheet completely covering one side of the plate. After metal is deposited on the open side the sheet is removed to the opposite side where the conductors have already been built up.

A wide metallized area of not less than 15 × 15 mm is provided at the plate border for making contact with the clamp (suspension) in the process of metal build-up.

General requirements to printed circuit boards. Usually printed circuit plates are made either square or rectangular. Their dimensions do not exceed 220 × 380 mm, since larger plates are not mechanically strong, are awkward for machin-

ing, apt to buckling in the process of printing circuit and soldering by the dipping technique.

The centres of all the holes on the printed circuit board are located at the intersecting points of the coordinate grid

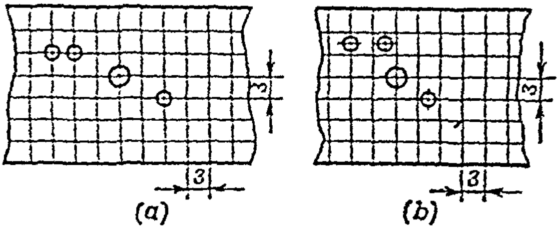


Fig. 125. Arrangement of holes on printed circuit board
a—right; b—wrong

spaced at 3 mm (Fig. 125). Sometimes a coordinate grid pitch of 1 mm is adopted. The hole centres for multicontact hook-up elements (relays, connectors, tube sockets), which by their design cannot be aligned with the coordinate grid intersection points, should be laid out in compliance with specifications or drawings for these elements and parts, so that the centre of a hole adopted

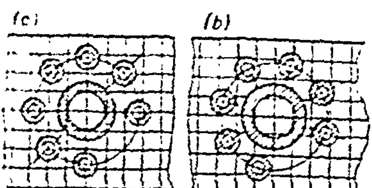


Fig. 126. Arrangement of holes for leads of multicontact hook-up elements
a—right; b—wrong

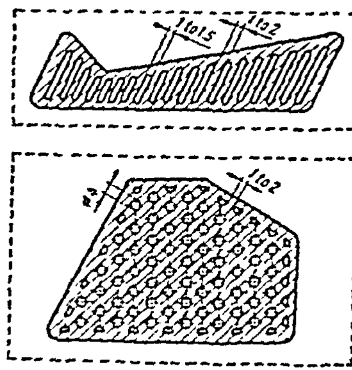


Fig. 127. Lattice shielding of conductors

as the basic one should be located in a grid intersection and the centre of one of the other holes—on one of its vertical or horizontal axes (Fig. 126).

The conductors are shielded by latticed screens (Fig. 127) with slots in the screen made at an angle of 45 to 60°.

Around holes for fasteners, transit and auxiliary holes in the screen there should be circular cutouts from 1 to 1.5 mm wide. If holes for the leads of hook-up elements happen to be in the screen area, a semicircular cutout from 1 to 1.5 mm wide should be made in the screen at a distance of 1 mm from the edge, so that the width of the bonding jumper does not exceed 1.5 to 2 mm. Sometimes semicircular grooves or sectors are made around the holes (Fig. 128).

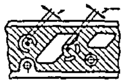


Fig. 128. Cutouts around holes in a shield

Generally the printed circuit plate is provided with at least two auxiliary holes and with a "key" (lug) due to which the plate can be located in one position only.

The drawing of a printed circuit plate (Fig. 129) should contain:

plate overall dimensions;

width designation of the printed conductors (the width of conductors up to 1 mm must be given in figures and wider conductors are plotted to scale with the coordinate grid);

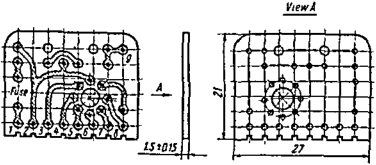


Fig. 129. Printed circuit board (drawing)

the distance between conductors (indications for spacings less than 1.5 mm only are required);

the marking of holes and symbols of circuit elements on the side of installation, bearing in mind that in usual

one-plate designs only holes for elements with flexible leads and transition elements (wire jumpers, plug connectors, terminal blocks) are marked, whereas in multiplate (sandwich) designs all the holes of the printed circuit board should be marked.

In addition, the following data are provided in the specification supplemented to the drawings:

the coordinate grid pitch (tolerance for non-parallelism of the grid lines is ± 0.1 mm);

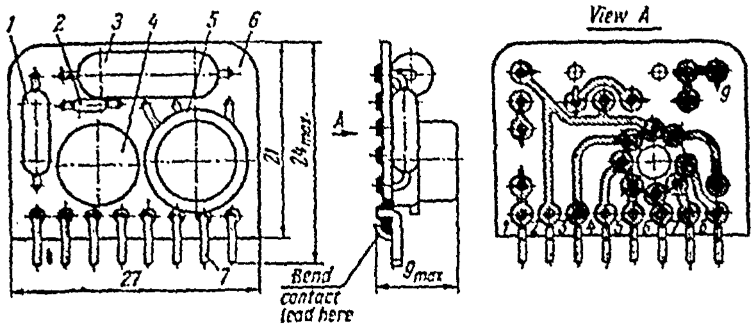


Fig. 130. Printed circuit unit (drawing)
1— diode; 2 and 3—capacitors; 4—transformer; 5—transistor; 6—board; 7—contact (terminal)

tolerance for the width of conductors (usually $+0.2$ mm in *narrow places and $+0.5$ mm in the other areas*);

the permissible digressions from the drawing in the location of conductors (usually ± 1 mm);

methods of marking the holes (in most cases the figures are located *symmetrically to the axes of the holes and* are marked in special white paint or by etching).

The grade of plate surface finish after machining and drilling holes should be not worse than $\nabla 4$. In machining, one of the plate holes is adopted as a reference point. The plate edges should be used for this purpose as a rare exception only. The spacings from the reference hole and any other hole should be accurate to ± 0.2 mm if not specified otherwise. Other not specified dimensions are to the 7th class of accuracy.

The drawing of a printed circuit unit given in Fig. 130 represents a printed circuit plate with hook-up elements, bridging (connecting) elements (jumpers, terminal blocks, etc.) and elements secured mechanically (by flanging out, riveting, etc.) with subsequent soldering. All the hook-up elements are marked in accordance with the circuit diagram. In addition, the specifications should ascertain the method of soldering of element leads and protection of the printed unit with varnish, and specify the materials used.

28. Fabrication of Printed Circuit Boards and Wiring of Hook-up Elements

The methods of fabrication of printed boards are classified by the techniques of obtaining a current-conducting coating and producing printed conductors.

Methods of obtaining current-conducting coatings. Several methods of producing current-conducting coatings are known.

Electrochemical (electrolytical): in this method a thin layer of metal (1 to 2 μ) is deposited chemically to a required thickness in an electrolytic bath.

Electrolytic-and-transfer method in which the conductors are preliminarily deposited electrolytically on a special metal matrix with subsequent transfer of the conductors onto an insulating base.

Foil application: a sheet of electrolytic copper foil is glued to one or both sides of an insulating base.

Burning-in of current-conducting dyes: silver compounds in a paste form are applied to the surface of an insulating base; during subsequent kilning the compound is reduced to metal and fused with the base.

Schoope process: in this method molten metal is pulverized onto the insulating base with the aid of an air-sprayer.

Vacuum flashing (as a version of cathode sputtering): a metal, pulverized in vacuum, is deposited on an insulating base in the form of a thin film owing to either sublimation or the action of an electric field.

Pressing of metallic powders; in this method powdered metal is pressed into the insulating base by means of a pre-heated die.

Methods of depositing printed conductors. Printed conductors are formed on the insulating base with the aid of stencils bearing the image of the conductors and enabling this image to be reproduced on the base. The stencils can be in the form of photographic diapositives or negatives, offset printing forms, grids with the conductors represented, molds, dies, templets, etc. The following methods of depositing conductors are used depending on the stencil employed:

Photographic—contact printing of the conductor image from photographic diapositives or negatives on a base coated with light-sensitive emulsion.

Offset—application of the positive or negative image of the conductors onto the base using protective varnish and printing forms.

Graphic—application of the positive or negative image of the conductors onto the base with protective dye through a reticulated stencil.

Molding—formation of a positive relief image of the conductors in the form of grooves on the plate.

Stamping—cutting out conductors with a special die out of a sheet of foil applied to the insulating base.

Impressing—deposition of acid-resistant films with a positive or negative image of the conductors by means of a heated die and coloured foil.

Xerographic—photographing the positive or negative image of the conductors by projecting them on a plate covered with a semiconducting layer charged to a preset potential. The latent electrostatic image is developed with the use of charged pigmented powders and is transferred onto the base with the aid of an intermediate backing, and then is flashed off.

Engraving—formation of the positive relief image of the conductors in the form of grooves with the use of special tools.

Drawing—application of the image of the conductors to the foil-clad insulating base in acid-resisting dyes either by hand or using a brush or lettering pin.

Application of a protective dye through a stencil.

Methods of fabricating printed circuit boards. The method of fabrication of printed circuit boards is a combination of a certain technique of fabricating a current-carrying

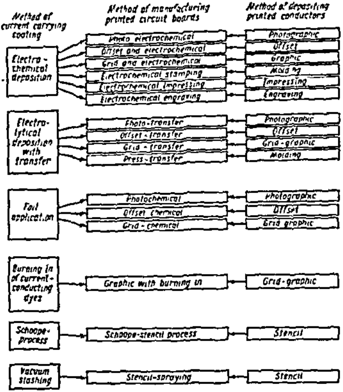


Fig. 131. Methods of deposition of conductors and current-carrying coatings used with various methods of production of printed circuit boards

coating with this or that method of depositing the image of conductors.

The diagram of Fig. 131 represents the methods of manufacturing printed circuit boards consisting of two principal technological processes: formation of a current-conducting coating and deposition of the image of the printed conductors. In certain specific cases, as for obtaining printed circuit plates on fragile bases, combined methods comprising three or more technological processes are employed. For example, the method of electrochemical deposition with subsequent etching on a drawn stencil, the Schoope process with subsequent etching with the use of photo-stencils,

and others. Most commonly used are photo-electrochemical, offset-electrochemical, grid-electrochemical, photographic transfer, grid-transfer, photo-chemical, offset-chemical, and grid-chemical methods.

Technological requirements to hook-up parts. Automation and mechanization of the assembly of printed circuits to a great extent depend on the design of the leads of hook-up component parts.

From the technological point of view a round-wire lead is the most practicable (then the hole in the plate for fastening this lead is also round). In addition, the round shape of the leads enables them to be sheared off and bent by comparatively simple devices. Generally round-section leads are 0.8 to 1 mm in diameter and are either tinned or silvered. The designs of intricate-shape hook-up components to be used in printed circuits should ensure the possibility of automatic assembly and maximum utilization of the advantages of the printed circuits.

Thus, large components are secured to the plate not only by soldering them to the current-conducting leads but also with the aid of special lugs projecting from the bodies; these lugs are soldered either to individual sections of the foil or to the grounded wide common conductor. These components or units are provided with special projections or grooves which ensure the ease of their transportation along the guides of automatic assembly machines with simultaneous orientation of the components warranting their proper installation on the plate.

The design of fastening and locating elements used in printed circuits should contribute to mechanized and automated assembly of components. Elements are adapted for mounting on printed circuit boards using for this purpose holes located on a coordinate grid of 3 mm pitch.

Radio elements should be of small physical size and simple geometric shape, preferably cylindrical; size tolerances should be not more than ± 0.25 mm. Polar radio elements as well as elements with three and more leads are provided with a "key" for their orientation in the process of fitting to the printed circuit board with the aid of an automatic stacker. Miniature radio elements are made with axial leads.

In broadcasting equipment operating without mechanical loads large-size units (tuned circuits, transformers, chokes) are sometimes secured with the aid of clamps or fastening clips with subsequent soldering.

Component parts fitted directly to a printed circuit board (for instance, tube sockets) should be of such a design as to exclude the possibility of varnish penetration to the radio elements (such as tube socket lugs), when the board is being painted. The materials used for radio devices and elements should permit heating them to 100°C for 30 hrs.

Methods of fitting hook-up elements to printed circuit boards. Prior to soldering all leads of hook-up elements

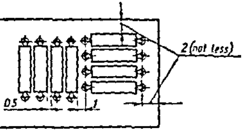


Fig. 132. Arrangement of hook-up elements of plate

as well as wire jumpers are secured in the board holes to prevent them from falling out during station-to-station transfer and soldering.

The leads of elements are passed through the holes and then bent underneath the board. The bent section should be at least 0.6 mm long and the point of bend not closer than 2 mm to the element body The length of the lead from the radio element body to the point of soldering should conform to corresponding specifications.

The distance between the body or lead of an element and the board edge should be not less than 2 mm (Fig. 132), between adjacent elements or units—not less than 0.5 mm, and not less than 1 mm from the radio element to the centres of holes for other radio elements arranged at right angles.

In double-plate ("sandwich") constructions hook-up elements are arranged vertically between two printed circuit

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Methods of fitting hook-up elements to printed circuit boards. Prior to soldering all leads of hook-up elements

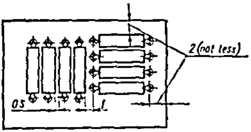


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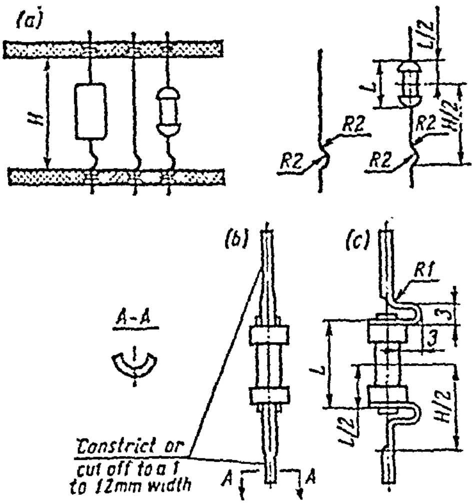


Fig. 133 Fastening radio elements with round axial leads (*a*) and flat radial leads (*b* and *c*) on double-plate units

boards. Circuit elements with round axial leads are fastened between the boards bending one of the leads (Fig. 133*a*); radio elements with flat radial leads are fastened by the non-constricted or non-sheared section of the lead (Fig. 133*b*) or by bending the lead (Fig. 133*c*). The constricted lead is secured in the hole by spreading out or twisting during shearing.

In flat printed circuit units hook-up elements are arranged parallel to the plate surface either without any spacing or with a 2-3 mm clearance between the element body and the plate. To protect the trimming elements (such as inductance coils) from varnish in the process of dip-coating, their bodies are raised 3 to 5 mm above the plate surface (exposed contacts of terminal blocks, relays, mounting racks are raised from 5 to 10 mm).

Hook-up elements with round axial leads as well as elements with flat radial leads in flat units are fastened by bending the leads (Fig. 134*a* and *b*). Sometimes the flat radial leads are secured without bending them (Fig. 134*c*). The hook-up elements are located on one side of the plate only (the side free of printed elements).

General requirements to printed circuit units. Printed circuit units are designed with due consideration to the peculiarities of printed circuit wiring and the methods of fabrication of boards. The printed circuit units can be

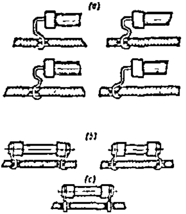


Fig. 134. Fastening radio elements on flat units

a and *b*—bent leads, *c*—straight leads

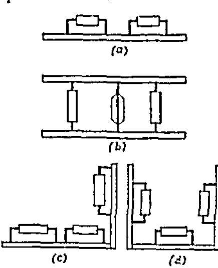


Fig. 135. Design of printed circuit units

a—single-plate, *b*—double-plate ("sandwich"), *c* and *d*—units consisting of two and three plates [illegible]

single-plate (Fig. 135*a*), double-plate (Fig. 135*b*) or composite, consisting of two, three and more single-plate units (Fig. 135*c* and *d*).

Hook-up elements are arranged on the plate in a way which allows us to avoid harmful effects of solder in the process of dip-soldering. For this reason in a single-plate design all elements are located on one side of the plate (Fig. 135*a*) irrespective of their destination and size, and in the double-plate design—between the plates in a vertical position (Fig. 135*b*). It is not advisable to arrange the hook-up components on the outer sides of the plates or to introduce a third plate in "sandwich" designs.

Hook-up elements are arranged on a plate in [illegible] a definite order (Fig. 136*a*). Though there are certain [illegible]

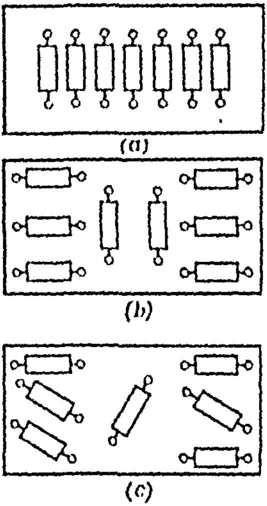


Fig. 136. Arrangement of hook-up elements on mounting board
a — in rows; *b* — at an angle of 90°; *c* — at random (wrong)

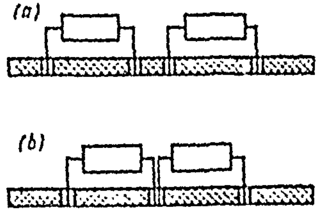


Fig. 137. Fastening leads of hook-up elements
a — right; *b* — wrong

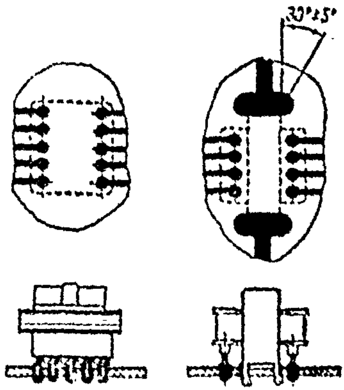


Fig. 138. Attachment of a small-size transformer to board

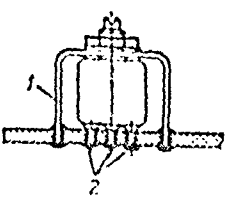


Fig. 139. Fastening a potentiometer with the help of a bracket

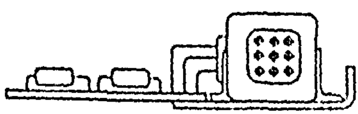


Fig. 140. Arrangement of a large-size component

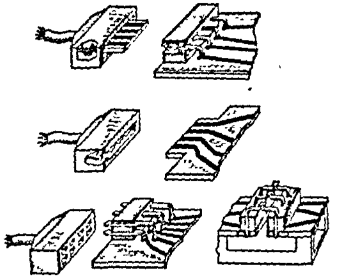


Fig. 141. Connecting (bridging) elements

tions from this rule, as shown in Fig. 136b, it is no good practice to arrange parts at different angles to each other as in Fig. 136c. Another requirement is that the conventional axis passing through the fastening points of two output hook-up elements should be parallel to the major direction of the maximum mechanical stresses affecting the unit.

Leads of hook-up elements are fastened in plate holes. Each hole should accommodate only one lead (Fig. 137). Elements and units with many leads (such as miniature transformers, plug connectors) are secured to the plate in a manner depending on their design features and mechanical strength of the plate.

Figure 138 illustrates methods of fastening miniature transformers on a plate. Heavy or special elements are attached with the aid of brackets *1* (Fig. 139) thus preventing rupture of leads *2* under the action of mechanical stresses.

Bulky and heavy elements, components and units (such as power transformers) are located outside the plate (Fig. 140) and are connected either by multistrand wire jumpers or by means of special terminal blocks soldered onto the plate using the "gang soldering" method.

Connection of the plates is achieved with the aid of connecting elements (plug connectors, terminal blocks) mounted in a way similar to hook-up radio components (Fig. 141). In case of fast fitting of two plates *2* normal to each other with conductors *3* located on chassis *1* connections are made with the aid of "tenon joints" as illustrated in Fig. 142. In composite U- and L-shaped structures, it is not practicable to use hook-up elements as connecting means between plates.

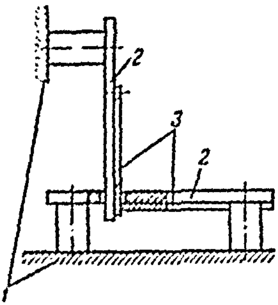


Fig. 142. Connection with the use of a "tenon"

Upon complete assembly the printed circuit unit is coated with varnish.

29. Soldering of Circuit Elements in Printed Circuit Boards

The major technological problem in manufacturing radio equipment with the use of printed circuit boards is the problem of soldering circuit elements.

The arrangement of all circuit elements in one plane on separate plates creates favourable conditions for the mechanization and even automation of soldering connection wires. The mechanization of soldering operations in the manufacture of radio equipment results in a marked reduction in labour consumption and improvement of the equipment quality. Preparation of the printed circuit boards for soldering, the composition and characteristics of the fluxes and solders used, temperature of the soldering bath and its stabilization, the time during which the board is in the bath with molten solder, etc.—all these factors are of prime importance.

Dip-soldering is one of the simplest and most extensively used methods of mechanized soldering of printed circuits. The method permits simultaneous soldering of scores of joints. Even when performed manually it is a definite step towards mechanization. But simply dipping the work into solder does not always ensure high-quality joints. A common trouble in this method are individual

cold-soldered joints of the elements across the entire board thickness, solder "icicles", etc. To eliminate these disadvantages, the plate is soldered under vibration. Other methods of soldering circuit elements are also in use: selective soldering with the aid of protective masks, "solder wave" method, and others.

Features of soldering electric wiring on printed circuits. Basically, soldering printed circuits does not differ from the manual process performed with a soldering iron, though the following rules of soldering technique must be of particular concern:

plate conductors and element leads to be soldered should be free of oxidation or dirt;

during soldering the surfaces being joined should be heated to a temperature equal to or slightly above the solder melting temperature;

the flux employed should be most effective in the range of the bath working temperatures and provide good quality of soldering.

To ensure these conditions, particular attention must be paid to storing the plates prior to mounting elements on them. To prevent oxidation of the surfaces of conductors, the printed circuit boards should be subjected to preservation treatment in storage, especially in case of a circuit manufactured by the chemical method. Most economical is the technique of preservation of the boards by applying paraffin-stearine flux. This method provides satisfactory soldering without additional application of flux prior to submerging the boards into molten solder. In the course of preservation treatment of particular importance is the protection of places of future joints. Recently a new installation for selective application of flux has been developed; it yields good results in combination with selective or "wave" soldering.

Whereas boards with an electroplated circuit have a layer of deposited tin or solder ПОС, the circuits manufactured from foil-coated materials should be tinned beforehand (either by electroplating, or dipping). This is due to the fact that active (acid) fluxes cannot be used for soldering radio elements and that acid-free fluxes have insuf-

ficient deoxidating ability and are mostly used for protection purposes.

The leads of radio elements after prolonged storage under standard atmospheric conditions are heavily oxidized and are very difficult to solder even with the use of a soldering iron; they should be first tinned by dipping.

The soldering bath should have a thermal "reserve", that is it should rapidly compensate the losses of heat introduced by the plates under shop conditions. The temperature of the soldering bath is automatically maintained constant within ±5°C limits.

Dip-soldering. Let us consider the dip-soldering method as an example of the mechanization of soldering of printed

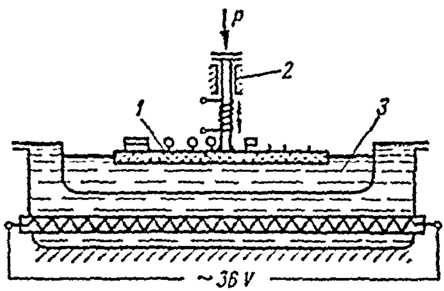


Fig. 143. Dip soldering installation (sketch)

circuits in the process of production. The dip-soldering installation is illustrated in Fig. 143; the detail of the method is given below.

Board *1* with radio elements mounted on it is fastened on a special fixture, put on the vibrating head *2* and immersed into the bath with molten solder *3* at 225 to 230°C. The depth of dipping the board is equal to 50-70 per cent of its thickness. The board is kept in this position for 2-3 sec following which the vibrator with an amplitude of 0.1-0.3 mm and 100 c/s frequency is switched on. Vibration facilitates the penetration of solder into the plate holes (thorough soldering) and enables forming a joint of proper shape.

To reduce the expenditure of solder, the plate conductors from the soldering side are primed with ground coat 138A

this protects them against tinning. The conductors are coated with the help of a pulverizer through a slotted metal stencil and are dried in an infra-red dryer on the conveyer line for 30 min at 90 to 100°C.

The dip-soldering process has certain disadvantages. It requires a narrow margin of temperature conditions in the bath, since at 232°C partial melting of the electric-plated tin on the conductors under the prime coat takes place and the protection of conductors becomes useless; whereas at 225°C good soldering is not guaranteed and the duration of the process increases considerably (from 15 to 20 sec). Moreover, when immersed into the flux at 120°C, the plate preheated to 70-80°C (to reduce the subsequent thermal shock) takes up too much flux thus making soldering more difficult and heavily contaminating the plate, in particular, the tube socket lugs. A common defect of dip-soldering is swelling or blistering, i.e. local delamination of the plate.

Selective soldering. The selective soldering technique, i.e. dip-soldering with masking certain areas, is also used. The masking is achieved with the aid of varnished fabric, varnished glass-fibre fabric, organo-silicon rubber, paper. In common use is organo-silicon rubber brands 14-P-2 and 14-P-15 and paper. Rubber, however, is affected by the soldering process, it swells and loses thermal resistance.

A paper masking stencil is much more convenient. It has openings in the points of soldering only. First it is impregnated in a stearine-paraffin flux, then it is fitted onto the plate and together with the latter is installed into the soldering device. The use of the stencil impregnated with flux sharply reduces conductor swelling, modifies the thermal shock to the plate, makes it possible to exclude plate treatment with flux before immersion into the soldering bath, enables the temperature of the soldering bath to be elevated to 245 ± 5°C, thus rendering the reduction of soldering time to 8-10 sec possible.

Selective soldering with positive feed of solder. In this method molten solder is [illegible] to be [illegible]

on master mask *3*, provided with nozzles, and is pressed to it by means of several stops. Vibrator *1* imparts oscillations to the solder through a bronze diaphragm. The required amount of solder *6* is forced by piston *4* through the nozzles in the master mask *3*, soldering the joints. The solder is melted by heating elements *5*. The bath is placed in refractory lining *7*.

A feature of the selective-soldering method is that the printed circuit board is heated only in the points of solder-

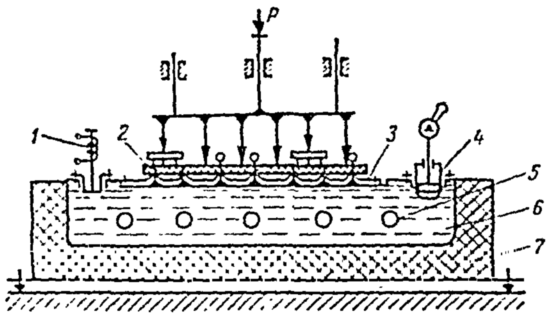


Fig. 144. Schematic diagram of selective-soldering installation

ing; the conductors remain cold thus excluding their swelling. Buckling of the board is reduced approximately four times as compared to the dip-soldering technique. In addition, the selective-soldering method ensures a soldered joint throughout the entire board thickness, permitting the application of overheated solder (260-300°C). On flat boards without grooves the current-conducting lines need *not be coated with varnish.*

This soldering method can be recommended for series or mass production only since each type of printed circuit board requires a separate master mask with nozzles.

"Wave" method. The schematic diagram of soldering printed circuits by this method is shown in Fig. 145. Printed circuit board *1* is moved over the crest of a stable wave of solder *4* forced through a special slot-shape nozzle *2*. The speed of the board movement is determined experimentally. The solder is melted by heating elements *3*. The bath is placed within refractory lining *5*.

In this method the solder, which is in constant motion, carries much heat which enables the soldering to be boosted up. Due to constant movement, the solder is void of a surface oxide film. At the same time surface tension of the

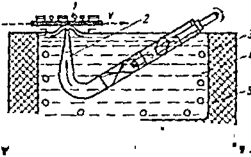


Fig. 145. Schematic diagram of installation for "wave" soldering

solder is easily disturbed by the moving board, thus facilitating wetting. Besides, the joint surfaces are well wetted by the solder. The wave method makes it possible to automate the process of soldering printed circuit boards.

CHAPTER FIVE

RADIO MEASUREMENTS

30. General

Modern radio equipment is noted for the complexity of its circuits and large number of interacting units. The proper assembly and adjustment of a radio apparatus requires a vast variety of radio measurements to estimate different parameters. A value is measured by way of comparing it to a conventional standard, which is the unvariable unity of this value (measurement unit). The value measured is compared to the measurement unit with the aid of measuring instruments which in their turn are compared to the standard unit by graduation.

Measurements are always made to a definite accuracy and approximation. The accuracy of measurement is determined mainly by the precision of the measuring instruments used, the purpose in hand and the measurement technique. Thus laboratory measurements require greater accuracy than measurements carried out in the process of assembly and adjustment of radio equipment, since in the first case it is necessary to estimate the operation of the apparatus, whereas in the second case one should only make certain that the apparatus parameters comply with specifications.

One should not quest for the measurement accuracy greater than is necessary to determine the effect of the value on the apparatus operating conditions, since more accurate measurements will take up much time and require the use of more complex and expensive measuring instruments.

However the correctness of results obtained does not entirely depend on the accuracy of the measuring instruments used. This conclusion is easily arrived at, if several measurements are made by one and the same instrument under identical conditions. No matter how meticulously

the measurements have been performed, their results will not be exactly the same. This is explained by the fact that measurement results are dependent on many factors which change incessantly.

In most cases measurements are made to appraise the behaviour of a circuit in operation, therefore the connection of measuring instruments must not affect the circuit operating conditions appreciably. The connection of measuring instruments might detune the circuit, change operating conditions of tubes and induce spurious feedback. These effects occur even in audio frequency measurements while in high- and especially ultrahigh-frequency measurements they are almost unavoidable, if certain rules of connecting measuring instruments to the circuits under test are not observed.

Let us discuss how to connect a measuring instrument to a circuit so as not to disturb its operating conditions appreciably. If the measuring instrument is connected to the circuit in series, its intergal resistance should be smaller as compared to the circuit resistance. When it is connected in parallel, its internal resistance should be greater as compared to the circuit resistance measured between the points to which the instrument is connected. If the measuring instrument is connected in place of a detached element of the apparatus, the input resistance of the instrument should be equal to the input resistance of the disconnected element.

In transistorized circuits, in contrast to electron tube circuits, a part of the transistor output power is coupled to the input, i.e. there is a certain amount of feedback. This imposes specific demands on the accuracy of matching the measuring instrument resistance with that of the circuit stage disconnected for the time of measurements, since misalignment of the output circuit will bring about a misalignment of the input, and hence, of the entire circuit. In addition, since the input resistance of transistors is small (of the order of hundreds of ohms at 100 kc/s frequency), they consume considerable power from the signal source and heavily shunt the output circuit of the preceding stage.

The degree of mismatch in ultrahigh-frequency measurements is of prime importance. The slightest mismatch will

result in reflections of high-frequency energy distorting the measurement data. The instruments used for measurements in these frequencies are connected by means of special connecting devices.

Parameters are measured by different methods under diverse conditions with the use of various test equipment. This is of great importance, since it makes it possible to substitute unavailable instruments (or instruments of the required class of accuracy) with other instruments, using an appropriate method of measurement of the magnitude.

Thus, voltages can be measured not only directly by a voltmeter but also indirectly, determining the current passing through a known resistance. Resistances are measured by the bridge method and also by the ammeter-voltmeter method or with a voltmeter only. Thus, various measurements can be performed with the use of a comparatively small set of measuring instruments.

This, however, requires a good knowledge of the operating principle of the instrument and its peculiarities. Before performing measurements with an instrument, it is necessary to get familiar with its design by reading the reference book or instructions that go with the instrument. Special attention should be paid to directions regarding the accuracy of graduation and particulars of reading out the values measured. Much attention should also be paid to the choice of instrument, determination of the measurement range and estimation of the measurement errors.

In the following chapter we shall discuss the principal types of instruments which can be widely used in the process of assembly, adjustment and testing of radio equipment.

31. Indicating Instruments

Indicating instruments are employed mainly for the measurement of d.c. voltage and current in various radio circuits as well as for the measurement of resistances, if the instrument design offers such a possibility. Indicating instruments intended for the measurement of a.c. voltages and currents are characterized by a narrow frequency band (50-1,000 c/s) and are suitable for measuring voltage and

current values in power supply circuits only (tube filaments, power transformers).

The measurement accuracy depends on the accuracy [illegible]

and 4. The error is expressed in per cent of maximum scale value. To illustrate: an instrument of accuracy class 1 in the 1-300 V range is to guarantee ±1 per cent accuracy from full-scale value 300 V, i.e. ±3 V, and this absolute error (±3 V) is retained over the entire scale range. Hence, when measuring say 3 V voltage (using this scale) the relative error may be ±100 per cent. Therefore the measurement range of an instrument should [illegible] of the values measured should [illegible] scale and not at its beginning, [illegible] error. The basic types of electric indicating instruments are discussed below.

Multimeter instruments (circuit-analysers) are portable commercial-type direct-reading instruments designed for the measurements of current and voltage values in d.c. circuits, voltage and current values in a c. circuits at 50 to 1,000 c/s frequencies, and d.c. resistance. They can be used at −15 to +35°C ambient temperatures and up to 80 per cent relative humidity.

Usually circuit-analysers are equipped with a set of connecting wires with changeable probes and adapters.

During measurements the instrument should be protected from electric fields and other kinds of interference. The instrument indicating system should be accurately adjusted, i.e. the instrument pointer should be preliminarily set to zero by the scale corrector. However normal operating conditions alone do not guarantee measurements within the given accuracy class. Of great importance are proper connection of the instrument to the circuit under measurement and observance of measurement regulations.

On positioning the instrument it should be set to the appropriate range. If the value of voltage or current is not known (roughly), the instrument should be first set to the maximum range so as to avoid overloading and pointer "kicks" which might impair the instrument indicating

system. Care should be taken not to make any commutations of the instrument under current, since this can damage the instrument or disturb its calibration.

For resistance measurements the instrument should be set to zero on the resistance scale. For this purpose switch the instrument to resistance measurements, bring the probes into contact, and with the zero-adjustment knob bring the instrument pointer to the scale zero mark (the zero mark is at the right hand side of the ohmmeter scale). Passing over to another measurement range check zero adjustment of the pointer.

Multimeter type Ц430 is designed for the measurement of a.c. and d.c. voltages, direct currents and resistances. The instrument circuit diagram is illustrated in Fig. 146. Direct current is measured with a pointer microammeter furnished with shunts $R_{18}-R_{24}$ and R_{29}. For constant voltage measurements multipliers R_1-R_8 are connected in series with the respective terminal, and resistances R_9-R_{16} (through a copper oxide rectifier) for alternating voltage measurements.

Power supply for resistance measurements is obtained from four galvanic cells type 1.3 ФМЦ-0.25 contained in the instrument of which only one is used for measurements in the ×1; ×10; ×100 measurement ranges, and all four—in the ×1,000 range. The instrument is adjusted to zero (for resistance measurements) with the aid of variable resistor R_{17} whose knob is located on the front panel.

The type of measurement is selected by setting the switch in any of the positions marked (=, ~, Ω) the range is selected by inserting the lead plug into an appropriate socket on the front panel.

The fundamental error in d.c. voltage and current measurements does not exceed ±3 per cent of the scale range; ±4 per cent for alternating-current measurements at 50 c/s frequency; and ±10 per cent for resistance measurements. The frequency error for measurements of a.c. voltages at frequencies above 1,000 c/s does not exceed ±4 per cent of the scale range.

Measurements should be performed with the instrument in a horizontal position. Overall dimensions of the instrument are 215 × 115 × 75 mm; weight—about 1.6 kg.

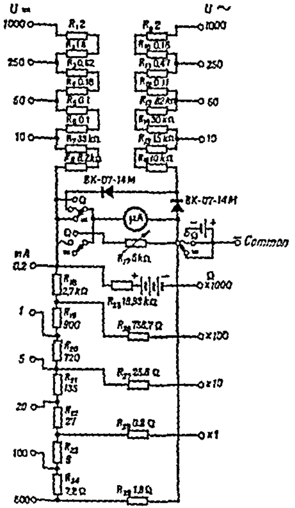


Fig. 146. Schematic diagram of circuit-analyser type Ц430

Multimeter type Ц55 is a commercial-type multimeter rectifier-type direct-reading instrument. It is designed for d.c. and low-frequency a.c. measurements of voltage and current and d.c. resistances, and has an additional decibel scale (db). The instrument is used for radio measurements in laboratory, work-shop and field conditions.

The fundamental error for voltage and current (d.c.) measurements does not exceed ±3 per cent of the full scale value on the range used, and ±5 per cent for a.c. measurements at 50 c/s current frequency. For resistance measurements the error is about ±10 per cent. Variations in instrument readings with the change of a.c. frequency from 50 to 1,000 c/s do not exceed ±4 per cent. Frequency error for the 6 kV measurement range is not specified.

For a change of ±10 per cent in ambient temperature, the complementary error will be not more than:

±1.5 per cent for resistance measurements in the temperature range from 20 to 50°C, and ±2 per cent in the range from −10 to +20°C;

±2 per cent for d.c. measurements (voltage and current);

±3 per cent for a.c. measurements (current and voltage) in the temperature range from 20 to 50°C, and ±6 per cent in the range from −10 to +20°C.

When used as an ohmmeter, the instrument is powered by 1.5 V battery in the 3 to 300 kΩ range, and by 22.5 V battery in the 30 MΩ range.

The test voltage for testing the insulation resistance is 5 kV. The overall dimensions of the meter are 270 × × 220 × 220 mm, and the weight is 8.5 kg.

32. Waveform Analysis Instruments

Waveforms of signal are analysed by various types of oscilloscopes. The most commonly used is the cathode-ray oscilloscope. The instrument is particularly useful during adjustment and analysis of radio circuits.

When using an oscilloscope as well as any other instrument one should take into account the effect of its input circuits on the parameters of the circuit under test; this effect may be quite notable.

The cathode-ray oscilloscope type C1-1 is designed for the analysis of periodic electric phenomena and processes of a non-electric nature which can be converted into electric. It is used for the measurement of voltage, frequency, phase, and duration of a process, depth of modulation, etc. The C1-1 oscilloscope characteristics are listed below:

1. Sensitivity of the vertical deflection amplifier is 4 mV eff/cm and the amplification factor is 1,800. Frequency response is flat to ±1 db in the 2 c/s-250 kc/s range, and to 6 db at a 500 kc/s frequency; the input resistance is 2 MΩ ± 20 per cent.

2. Sensitivity of the horizontal deflection amplifier is 220 mV eff/cm and the amplification factor is 35. The frequency response is flat to ±1 db in the range of 2 c/s-200 kc/s, and to 6 db at 300 kc/s; the input resistance is 5 MΩ ± 20 per cent.

3. The input attenuator range is 1 : 1; 1 : 10; and 1 : 100 ± 15 per cent in the 2 c/s to 250 kc/s frequency range.

4. Resistance of external synchronization input is 0.1 MΩ ± 25 per cent.

5. Frequency range of the continuous scanning oscillator is 2 to 7; 7 to 30; 30 to 130; 130 to 500 c/s; 500 c/s to 2 kc/s; 2 to 7; 7 to 25; and 25 to 50 kc/s; scanning non-linearity is 5 per cent.

The instrument is powered from the 50 c/s mains at 115, 127 and 220 V (+5, −10 per cent), consuming 120 W. Overall dimensions are 565 × 233 × 425 mm; weight—24 kg

In oscilloscopy of pulses, periodic and aperiodic waveforms, the measurement of short time intervals, viz. pulse durations, pulse rise time, oscillation periods, etc. is of particular interest. These measurements are effectively performed with the use of pulse oscilloscopes which feature a broadband of the vertical deflection amplifier, slave sweep, and a device for measuring small-time intervals (pulse-duration calibrator)

The shorter the analysed pulse, the wider should the passband be. Slave sweep makes it possible to examine single pulses or pulses with durations much shorter than their recurrence periods.

Duration calibrators generate time markers which are superimposed on the sweep trace as dark and bright dots. The time-in marker generator may be a sine wave or a pulse oscillator; its output voltage is applied to the control electrode or cathode of the cathode-ray tube for modulating brightness of the beam.

33. Tube Voltmeters

Tube voltmeters have found wide application in radio equipment assembly and adjustment. They are grouped into direct-current, alternating-current, and universal-type voltmeters; the latter are designed for d.c. and a.c. measurements. The d.c. voltmeter is in fact a d.c. amplifier with the indicator connected to the output amplifier, whose readings are in direct proportion to the input voltage being measured. An a.c. voltmeter comprises an amplifier and a detector.

Small-value voltages are measured with the use of amplifier-detector type voltmeters. The voltage measured is fed to an a.c. amplifier, the amplified voltage is rectified by a detector terminating in a pointer indicator. A drawback of this voltmeter type is that it has a comparatively narrow frequency range limited by the passband of the a.c. amplifier.

Voltages in a wide frequency range are measured with the aid of tube voltmeters of the rectifier type. The voltage to be measured is applied to the rectifier converting the a.c. voltage into a d.c. voltage with a magnitude equal to the a.c. amplitude. Direct voltage is measured by a device similar to that used in d.c. tube voltmeters. A drawback of the detector-amplifier type voltmeter is that it cannot be used for measuring voltages whose amplitudes are in millivolt range. Universal voltmeters are of the rectifier type; d.c. voltages are measured by applying them directly to the d.c. amplifier.

Some types of tube voltmeters are discussed below.

The universal tube voltmeter type B7-2 is designed for the measurement of direct and alternating high-frequency voltages in laboratories and production shops. A T-joint adapter head supplied with the voltmeter makes it possible to carry out measurements in coaxial lines in the range of 100 to 400 Mc/s. The range of voltage measurements on d.c. circuits can be extended with the use of voltage divider ДНС-8, and in a.c. circuits with ДНЕ-6 and ДНЕ-7 voltage dividers supplied with the voltmeter.

The B7-2 voltmeter basic technical data are listed below:

1. Voltage measurement range in case of direct connection to the d.c. or a.c. circuit is from 0.1 to 150 V. Alternating current is measured in the 20 c/s to 400 Mc/s range. The instrument has five subranges: 1.5; 5; 15; 50; and 150 V.

2. The fundamental error in measuring d.c. and a.c. voltages (at 50 c/s) does not exceed ±2.5 per cent of the scale range; ±3 per cent in the frequency range to 100 Mc/s, and ±15 per cent in the 100 to 400 Mc/s range.

3. Voltage measurement range with voltage dividers: ДНС-8—*to* 15 kV, *d.c.*; ДНЕ-7—*to* 5 kV, a.c. (20 *c/s to* 5 kc/s); and ДНЕ-6—to 5 kV, a.c. (5 kc/s to 30 Mc/s).

4. The voltmeter input resistance at 50 c/s is not less than 10 MΩ, not less than 50 kΩ at 10 Mc/s, and not less than 25 MΩ in measuring direct voltage.

5. Input capacitance of the voltmeter connecting probes is not more than 7 pF for the audio frequency probe, and not more than 3 pF for the r.f. probe. The resonance frequency is about 350 Mc/s for the audio frequency probe, and about 1,050 Mc/s for the r.f. probe.

6. VSWR of the T-joint adapter with the probe fitted into it is not more than 1.3 in the 100 to 400 Mc/s frequency band; VSWR with a dummy load is less than 1.1.

The instrument is designed for a.c. supply at 50 c/s frequency and 110, 127, 220 V ± 10 per cent voltage, with power consumption about 65 W. Overall dimensions are 210 × 270 × 210 mm; weight—10 kg.

The tube voltmeter type B7 is designed for the measurement of d.c. and a.c. voltages as well as for the measurement of resistances, capacitances and inductances.

B7 voltmeters feature the following characteristics:

1. The measurement range of d.c. voltages from 0.1 to 1,000 V is covered in seven subranges: 1; 3; 10; 30; 100; 300; and 1,000 V full-scale values. The measurement range can be widened to 10,000 V with the use of an external divider.

2. The measurement range of a.c. voltages is from 0.1 to 1,000 V in seven subranges: 0.1; 3; 10; 30; 150; 300; 1000 V.

3. The resistance measurement range is from 1 Ω to 100 MΩ in seven subranges: 100; 1,000 Ω; 10; 100 kΩ; 1; 10; 100 MΩ.

4. The inductance measurement range is from 100 μH to 10^5 H in six subranges: 1; 10; 100; 1,000; 10,000; 100,000 H.

5. The capacitance measurement range from 10 pF to 100 μF is covered by seven subranges: 100; 1,000 pF; 0.01; 0.1; 1; 10; 100 μF.

6. The input resistance in measuring direct voltages is 11 MΩ; in measuring alternating voltages with the high-frequency adapter in subranges 1; 3; 10; 30; 150 V is not less than 4.3 MΩ with a shunting capacitance not exceeding 7 pF; with the universal probe in subranges 300 and 1,000 V is not less than 9 MΩ.

7. The frequency range (with the high-frequency adapter) in subranges 1; 3; 10; 30; 150 V is up to 60 Mc/s.

8. Instrument error:

in measuring direct voltages on scales 1; 3; 10; 30; 100 V not more than ±3 per cent; on scales 300 and 1,000 V not more than ±4; and ±8 per cent of the scale range with the external voltage divider;

in measuring alternating sinusoidal voltage at 50 c/s on scales 3; 10; 30; 150 V not more than ±4 per cent; on scales 1; 300 and 1,000 V, ± 5 per cent of scale range;

in measuring resistances, ±10 per cent of the value measured;

in measuring inductances, ±15 per cent of the value measured.

The instrument is powered by the 50 c/s, 127 or 220 V mains and by 400 c/s, 115 V ±3 per cent mains, consuming 35 W. Overall dimensions are 309 × 233 × 192 mm; weight—8 kg.

34. Test Generators

The purpose of test generators is to produce signals of waveform amplitude and frequency. R.f. test generators, in addition, can produce modulated signals with a definite modulation depth. One of the principal requirements to test generators (and, indeed, any other signal sources) is a low output impedance. The lower the output impedance of a signal source, the lower is the influence of the circuit tested on the generator operation, and vice versa.

In most cases the output circuits of test generators are voltage dividers made up of low-resistance non-inductive resistors having small stray capacitance (usually bifilar wound-wire resistors). Such a divider (attenuator) provided at the output of a test generator makes it possible to vary the output voltage (which at the same time must be frequency-independent) within a wide range. Of particular importance is the frequency stability of the test generator and the possibility to vary frequency over a wide range.

Usually the entire frequency range of the generator is divided into several subranges with continuous control of frequency. In most cases the output voltage of the test generator is measured by an instrument calibrated in r.m.s. values

The standard-signal generator type Г4-1 is designed to test and align radio circuits. The basic technical characteristics of the generator are:

1. Frequency range extends from 100 kc/s to 25 Mc/s.
2. Frequency setting error is ±1 per cent.
3. Output voltage ranges from 0.1 μV to 1 V.
4. Operation modes: free signal; built-in amplitude modulation with a sinusoidal voltage at 400 c/s; external amplitude with a sinusoidal modulation voltage at 50 to 8,000 c/s.
5. Non-linear distortion with internal amplitude modulation is not more than ±5 per cent

The instrument operates on 110-220 V ±10 per cent a.c., 50 c/s. Power consumed is not over 120 W. The overall dimensions are 325 × 335 × 530 mm, and the weight is 25 kg

The standard-signal generator type Г4-5 is used as a source of calibrated sinusoidal r.f. voltages in radio equipment tests and alignment The instrument characteristics are as follows:

1 Frequency range, 150 to 1,000 Mc/s
2 Basic frequency setting error, not more than ±1.5 per cent
3 Operation modes: CW signal; external sinusoidal amplitude modulation with a voltage at 200 to 8,000 c/s; external pulse modulation with pulses from 2 to 10 μ sec duration, and 100 to 2,000 c/s repetition rate; internal

pulse modulation with rectangular pulses of 1 : 1 half-cycles, ratio at 1,000 c/s ±10 per cent; internal pulse modulation with pulses of 2 to 10 μ sec duration following at 100 to 2,000 c/s, externally and internally synchronized.

4. Outputs: power output, 0.1 mW to 1 W at a load of 75 Ω; microvolt output, 1 mV to 0.1 V at a load of 75 Ω; output voltage setting error, 25 per cent.

5. Pulse characteristics: pulse rise time not over 1.5 μ sec; decay time, not more than 2 μ sec (0.1 to 0.9); pulse duration setting error with internal pulse modulation, ±30 per cent +1 μ sec; error of pulse repetition rate setting, ±30 per cent + 100 c/s.

The instrument operates on 110; 127; 220 V ± 10 per cent, 50 c/s or 115 V ± 3 per cent at 400 to 800 c/s. Power drain is 270 W. Overall dimensions are 725 × 305 × 304 mm; the weight is 45 kg.

Audio frequency oscillator type Г3-4 is used as a source of sinusoidal audio and ultrasonic signals for testing and alignment of radio equipment. The basic characteristics of the instrument are:

1. Frequency range, 20 c/s to 200 kc/s (in three subranges).
2. Basic frequency setting error, not over ±2 per cent.
3. Output power, 0.5 to 5 W at 50; 200; 600 and 5,000 ohm loads.
4. Non-linear distortion, 0.7 to 1.5 per cent.
5. Frequency response is flat within ±0.5 db (relative to 400 c/s).

The instrument operates on 110; 127; 220 V, 50 c/s. Power drain is 150 W. The overall dimensions are 598 × × 357 × 293 mm; the weight is 32 kg.

35. Resistance, Capacitance, Inductance Measurement and Q-Meters

Resistance measurements. Radio circuits employ resistors with values from fractions of an ohm to hundreds of megohms. In most cases resistances are measured with ohmmeters and megohmmeters (ohmmeters are often included into circuit analysers). These instruments are usually multirange and direct-reading ones which is particularly

convenient in assembly and alignment of radio circuits. However, their accuracy is not very high, usually 5-10 per cent, and the scales of such instruments are non-linear.

Resistances can also be measured with a voltmeter and an ammeter (milliammeter), but the most accurate measurements are obtained by a universal measuring bridge. Measurements on a bridge usually amount to positioning the dials and adjusting the rheostat arm until the bridge is at balance and there is no current flowing through the null-detector connected across the bridge. The resistance value is indicated by the position of the dials calibrated in units of resistance. Radio engineering also uses other forms of resistance-measuring instruments. Consider some of them.

The tube megohmmeter type E6-2 is designed for measuring the resistance of conductors and insulators in the range from 1,000 to 100,000 MΩ. The entire range is covered by two scales and eight ranges. The fundamental error does not exceed ±1.5 to 2.5 per cent of the scale range.

The instrument operates on 110; 127; 220 V ± 10 per cent, 45-55 c/s, and consumes 30 W; the overall dimensions are 330 × 220 × 215 mm, and the weight is 8 kg.

The coaxial impedance meter type ШИСК-2 is designed for impedance and VSWR measurements in laboratories, shops and repair stations. The basic characteristics are:

1. Frequency range, 30 to 1,000 Mc/s.
2. Characteristic impedance, 75 Ω.
3. *Measurement ranges: in the range from 30 to 200 Mc/s*, resistances, 6 to 1,000 Ω, reactances, 10 to 3,000 Ω; in the range from 200 to 1,000 Mc/s, resistances, 6 to 1,000 Ω, reactances, 20 to 350Ω.
4. The voltage standing wave ratio, 1.04 to 3 in the 30 to 500 Mc/s range, and 1.05 to 2 in the 500 to 1,000 Mc/s range.
5. The error of measuring reactance and resistance in these ranges does not exceed ±20 per cent; for the VSWR *measurements it does not exceed ±5 per cent.* In the 30 to 200 Mc/s frequency range it does not exceed ±10 per cent for 12 to 500 Ω resistance, and 25 to 1,500 Ω reactance; for the VSWR it does not exceed 7 per cent in the 500 to 1,000 Mc/s frequency range.

The instrument is inserted into a gap in a 75-ohm characteristic impedance coaxial line. The overall dimensions of the instrument are 320 × 170 × 170 mm, and the weight is 17 kg.

The universal bridge type E12-2 is designed for measuring d.c. resistance, a.c. inductance and capacitance (at 100 to 1,000 c/s frequency), as well as coil Q-factor. The instrument consists of a universal bridge, audio frequency oscillator, balance indicator, tube voltmeter, and power unit. A microammeter with a 100-0-100 μA scale is the balance indicator; with its aid d.c. resistances are measured. A.c. resistance measurements are made by the same instrument with an amplifier incorporating automatic gain control. The instrument features the following principal parameters:

1. Measurement range: resistances—from 0.1 to 5×10^6 Ω, inductances—from 10 μH to 100 H, capacitances—from 10 pF to 100 μF, quality factor—from 0.1 to 500, loss tangent—from 10^{-3} to 0.5.

2. Measurement error: resistances — not over $\pm\left(1+\frac{2}{R}\right)$ per cent when in the range from 0.1 Ω to 1 MΩ (R—resistance in ohms), and ±3 per cent in the range from 1 to 5 MΩ; capacitances — not over $\pm\left(1+\frac{200}{C}\right)$ per cent in the range from 10 pF to 10 μF at 1,000 c/s (C—capacitance in pF), and not more than ±3 per cent in the range from 10 to 100 μF at 100 c/s frequency;

inductances—not more than $\pm\left(1+\frac{200}{L}\right)$ per cent in the range from 10 μH to 1 H at 1,000 c/s (L—inductance in microhenry), and not more than ±3 per cent in the range from 10 to 100 H at 100 c/s;

loss tangent—not more than $\pm\left(10 \pm \frac{0.1}{\tan\delta}\right)$ per cent when measuring over the entire capacitance range at 100 to 1,000 c/s frequencies (tg δ is the tangent measured value);

coil quality factor—not more than $\pm\left(10 \pm \frac{10}{Q}\right)$ per cent over the entire inductance range at frequencies from 100 to 1,000 c/s (Q—the quality factor measured).

The instrument operates at the mains at 110; 127; 220 V, 50 c/s; power drain—not more than 30 W. The instru-

ment dimensions are 598 × 357 × 293 mm; the weight is 21 kg.

The PBC-1-type instrument for calibrating resistors into tolerance groups enables the resistance deviation (polarity and value) from nominal to be read out in a range of ±20 per cent directly from the pointer deflection. The instrument is used in production-shop and laboratory conditions; with the aid of the instrument several thousand measurements per shift can be made. The measurements are carried out by comparing resistors with a reference resistance. The oscillator contains a measurement circuit, amplifier with an indicating instrument at its output and a regulated rectifier. Resistance measurement range is from 10^7 to 10^{12} Ω; measurement error is ±2 per cent in the range of up to 10^{10} Ω, and ±3 per cent in the 10^{10} to 12^{12} Ω range.

Capacitance measurements. Capacitance measurements are mostly performed in testing capacitors.

Prior to measurements the capacitors must be checked for short-circuits and leakage. The capacitors are tested for absence of short-circuiting with the aid of a d.c. probe-indicator and battery. The indicator is connected to the battery through the capacitor to be tested. The instrument pointer will not deflect, if the capacitor is in good condition. If the capacitor rating is large, the pointer will slightly deflect at the moment of connection and will then return to the zero position. Capacitor leakage is determined with the help of an ohmmeter (observing polarity, when electrolytic capacitors are checked).

The simple and efficient way of measuring capacitance is with the aid of direct-reading instruments, viz. faradometers and capacitance meters, as well as with bridges. If these instruments are not available, capacitance is measured by the voltmeter-ammeter method. This is done by measuring the voltage drop across a capacitor and the current passing through it, and using the equation

$$C = \frac{I}{2\pi f U}$$

where f is the frequency.

Capacitance can be measured by the reference method, if a box of standard capacitors is available, according to the diagram represented in Fig. 147.

It is more convenient to measure capacitance with alternating current by the comparison method, using the circuit shown in Fig. 148.

Small capacitance values (not over 0.01 μF) can also be measured by the resonance method.

Measurement of inductance and quality factor. Inductances are measured by the same methods as capacitances.

The bridge method is used for measuring inductances with accuracies to 1-3 per cent. The measurements are usually made at 1,000 or 100 c/s frequency. This method is

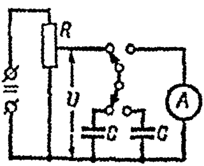


Fig. 147. Ballistic method of capacitance measurement

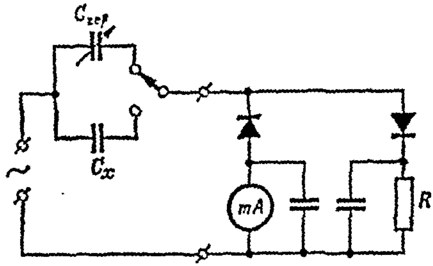


Fig. 148. Comparison method of capacitance measurement

mostly employed for the measurement of inductances of coils operating in low frequencies as well as in the long-wave (more seldom in medium-wave) range.

The voltmeter-ammeter method is used for the measurement of high-value inductances only. By this method the inductance of low-frequency chokes and transformer windings at 50; 400 or 1,000 c/s frequencies are measured.

In measuring the inductance of steel-core coils operating with magnetic bias, saturation of the core due to the bias current through the winding and, consequently, a sharp decrease in the coil effective inductance should be taken into account. For this reason when measuring the inductance of these coils by the voltmeter-ammeter method both alternating and direct currents are passed through their windings (Fig. 149).

In radio engineering various instruments for measuring inductances and capacitances are used; some of them are briefly discussed below.

The high-frequency inductance and capacitance meter type E12-1 is designed for measuring small inductances and capacitances with low loss factor under laboratory and production-shop conditions. The instrument has the following characteristics:

1. Inductances measured are from 0.05 μH to 100 mH in five subranges; capacitances measured are from 1 to 5,000 pF.

2. The measurement error for inductances does not exceed ±1.5 per cent of the value measured. The measurement error for capacitances does not exceed ±5 per cent.

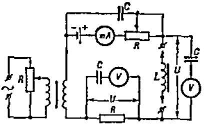


Fig. 149. Measurement of inductance of a coil with magnetic bias

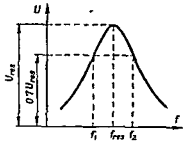


Fig. 150 Circuit resonant curve

3. Inductances are measured in a frequency range of 11 kc/s to 1.55 Mc/s and 300 to 700 kc/s.

Power to the instrument is supplied from 50 c/s mains at 110; 127; 220 V ±10 per cent. The instrument overall dimensions are 480 × 300 × 300 mm; the weight is 25 kg.

The Q-factor of a circuit is determined from the circuit resonance characteristic, which is the dependence of the circuit current on frequency. A circuit resonance characteristic is illustrated in Fig. 150.

The circuit Q-factor is determined from equation:

$$Q = \frac{f_{res}}{f_2 - f_1}$$

where f_{res} is the circuit resonance frequency
f_1 and f_2 are frequencies corresponding to a $0.7\ U_{res}$ level.

Various special instruments are employed in inductance and quality factor measurements; one of these is discussed below.

The low-frequency inductance meter type E7-1A is designed for measuring the inductance and quality factor of various coils at 50; 100; 400 and 1,000 c/s frequencies. The instrument characteristics are as follows:

1. Inductance measurement range is from 0.1 to 100 H in four sub-ranges. The measurement error is ±5 per cent depending on the value measured. The instrument enables inductance measurements with magnetic bias currents from 0 to 100 mA supplied from an internal power source, the coil active resistance being not more than 1,000 Ω.
2. The Q-factor of induction coils is measured at 50; 100; 400 and 1,000 c/s frequencies within 0.5 to 100 range. The Q-factor measurement error is ±10 per cent.
3. Inductance measurements are performed with a.c. voltages of 0.2 to 15 V depending on the inductance value and frequency.

Power is supplied from the 50 c/s mains at 110; 127 and 220 V ±10 per cent. Power drain is 280 W. Overall dimensions are 433 × 610 × 349 mm; the weight is 60 kg.

There are special instruments for measuring Q-factor called Q-meters. Measurement of the Q-factor by means of these instruments is based on the fact that the voltage across a tuned circuit is Q times greater than the emf. Q-meters consist of a high-frequency oscillator, measuring circuit, high-frequency tube voltmeter for measuring the voltage across the circuit, and a thermoelectric ammeter for measuring the current in the circuit feed line.

36. Vacuum Tube Tester

To test the quality and parameters of vacuum tubes, tube testers are used. We shall consider one of these instruments.

Tube tester type Л1-4 is designed for rapid checks of the degree of fitness of receiving tubes including low-power oscillator, kenotrons and gas-filled stabilizer tubes. The instrument makes it possible to check:

receiving tubes and low-power oscillator for short-circuiting between the electrodes, magnitudes of plate current

and transconductance; softness of vacuum, and intactness of electrode leads inside the tube;

kenotrons—for short-circuiting between electrodes and magnitude of rectified current;

diodes—for short-circuiting between electrodes and magnitude of plate current;

gas-filled stabilizers—for short-circuiting between electrodes, stabilization voltage and relative degree of stabilization.

The instrument is operative at -40 to $+50°C$ ambient temperature and up to 95 per cent relative humidity. Accuracy of the instrument is better than ± 5 per cent of any scale range.

The instrument is powered from 50 c/s 110; 127 and 220 V mains and from 115 V, 400 and 800 c/s mains, consuming 150 W. The instrument overall dimensions are $480 \times 280 \times 200$ mm, and its weight is 22 kg.

CHAPTER SIX

ALIGNMENT

37. General

The purpose of alignment and tuning is to compensate for deviations of component parameters which may impede the normal functioning of a radio apparatus as a whole, and to detect possible errors in wiring and assembly and other defects.

In aligning radio equipment it should be borne in mind that ageing of electric and radio elements brings about a deterioration of their parameters, that the equipment may operate under adverse climatic and mechanical conditions, and that assembly and wiring defects can also occur. For this reason an "operational reserve" in the output parameters of individual units, and subunits, and of the entire apparatus should be the aim of alignment and tuning.

Thus, in mass production, an average of one and a half assembly and wiring faults per one receiver set and up to four faults per TV set are revealed during aligning operations.

Proper and high-quality adjustment necessitates a thorough study of the apparatus which is to be aligned and tuned. One should get acquainted with the technical specifications, principal output and intermediate parameter values, general-view drawings, circuit, functional and other diagrams.

38. Assembly, Adjustment and Testing of Rectifier

ASSEMBLY

Electron and semiconductor devices in any kind of radio equipment can function normally only when the d.c. voltages, applied to their electrodes, are of stable magnitudes. As a rule, radio equipment is powered from a.c. mains and rectifiers are used to convert a.c. voltage to d.c.

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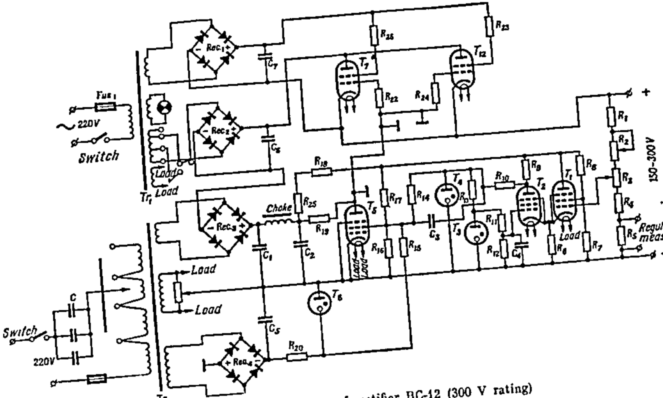


Fig. 452. Circuit diagram of rectifier BC-12 (300 V rating)

At present, various types of rectifiers, differing in power, magnitude of current and voltage rectified, ripple factor, and other basic parameters, are used in radio equipment. Despite the apparent diversity of designs all rectifiers can be united into several groups with the basic elements common for all rectifying circuits. Rectifying units are either fitted on the chassis of the radio apparatus, as is in most radio and TV sets, or constitute a separate unit.

In the assembly and wiring of a rectifier particular attention should be paid to the reliability of mechanical and electrical connections. All the circuit components should be thoroughly checked for their compliance with the specified requirements.

The process of assembly and wiring of a rectifier comprises a number of operations, such as the assembly of the body or chassis, installation of parts and soldering of wires connecting individual elements of the circuit.

Let us consider the wiring of a regulated high-voltage rectifier (Fig. 152). The rectifier is made on two chassis enclosed inside a casing one above the other. The upper chassis accommodates the regulator tubes type 6П7С and two selenium rectifiers: $Rect_2$ supplying the load circuits of the high-voltage rectifier and $Rect_1$ supplying the screen grid circuits of tube 6П7С. The transformer Tr_1 is also mounted here. The lower chassis carries the low-voltage rectifier, the d.c. amplifier of the electronic regulator, and the filament transformer. The upper and lower chasses are connected by means of a plug-and-socket connector. The upper chassis can be pulled out from the rear of the housing cover; the lower chassis is fitted to the front panel and is inserted into the housing from the front side.

Selenium rectifying disks are assembled in stacks. In assembly, particular attention should be paid to proper fitting of the current-collecting disk to the contact layer. The studs used for assembly are insulated with the aid of insulating cardboard coated with bakelite varnish. The assembled stacks are arranged between metallic frames (jaws) which are secured to the basic chassis by screws.

After assembly (prior to installation), selenium stacks are tested for direct and back current and for insulation strength. All transformers, chokes, base and partition

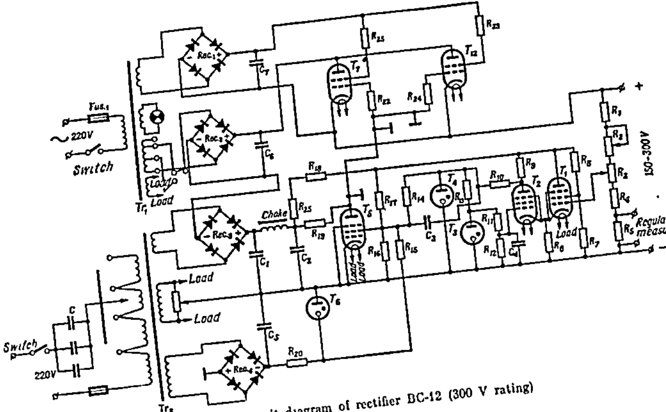


Fig. 152 Circuit diagram of rectifier BC-12 (300 V rating)

insulators are also tested for the insulation strength prior to installation. In certain cases (high-voltage rectifiers rated at 3 to 5 kV) the parts are tested for insulation strength after mounting on the chassis. The purpose of this test is to make certain that the insulation has not been damaged during fitting and fastening.

Switches and potentiometers are fitted to both sides of the panel with the use of nuts. To leave the panel face undamaged, the nuts on the inside side are tightened with a wrench.

Tube sockets for the d.c. amplifier regulator and stabilitron are fastened with the help of spring rings. The socket is fixed with the aid of a locating lug in the hole. The locating lug should be positioned as shown in the wiring diagram.

Indicating instruments are fitted to the front panel by screws with nuts and washers. The same method of fastening is adopted for plug connectors and fuses. The indicating lamp holders are secured with nuts. In assembling terminals, care should be taken to avoid bending of the insulating sleeves. They are to be accurately tightened by nuts without applying excessive force so as not to damage them.

The method of wiring a rectifier is as follows. The .c. amplifier and regulating tube circuits are connected ith a single-core tinned copper wire in pvc insulation tubing; the transformers, chokes and rectifier selenium stacks are connected with wire type ЛПРТС assembled into bunches. The transition from bunched conductors to stiff wiring is made on component leads and lugs (tube sockets, electrolytic or paper capacitors) or on wiring panels. The wiring panels are made of molded powder plastic with pressed-in lugs. The use of bunched conductors enables the wiring of one apparatus to be carried out at several working stations simultaneously.

Rectifier wiring is made with the use of several bun of conductors of intricate configuration. Since the cir elements are arranged in several planes (transformers chokes from above the chassis and other elements b the bunched conductors are made with the aid of dimensional templets. The bunched conductors are

up, following which the single wires are fanned out. The wires are checked for correct fanning out against the table of connections of the bunched conductors and wire ends marking. The insulation at the ends should be fastened beforehand and the ends tinned.

After laying out and checking the bunched conductors, the wire ends are soldered. This sequence of soldering is less labour-consuming than the alternate soldering with simultaneous laying out the wires, though the procedure requires greater attention on the part of the operator.

Before soldering, the wire must be mechanically fastened to the lug. It is more effective first to secure all the wires on one connecting panel or on the transformer terminal block and then to solder them. After soldering, the bunched conductors are fastened to the chassis with metal clips placing strips of thin insulating cardboard under them. After fastening the bunches the component wires should be straightened.

The wire ends are sealed with pvc tubing which is slipped onto the wire end only after soldering, otherwise it may be fused from the soldering iron heat. Filament circuits and *stand-off elements* on the front panel are wired with ПМВГ grade wire; wires leading to tube filament leads (pins) and mains switching-on tumblers should be twisted in pairs to eliminate a.c. interference.

In cleaning multistrand wire grade ПМВГ care should be taken not to cut the strands, as this might result in wire rupture during operation and in reduction of its cross-sectional area. For convenience, wires are colour-coded.

ADJUSTMENT AND TESTING

Prior to adjustment of the power supply unit, the operator should thoroughly study the circuit and wiring diagrams, know the purpose and arrangement of the apparatus components on the chassis or base frame, as well as the controls and switches. In addition to the necessary instruments the adjuster should have a laboratory autotransformer ЛАТР-1 or ЛАТР-2 which is required for a continuous variation of the primary (main) voltage.

The schematic diagram of primary voltage adjustment with the aid of a laboratory autotransformer is illustrated in Fig. 153. The autotransformer has one layer of winding on a toroidal core. On one of the end faces of the winding

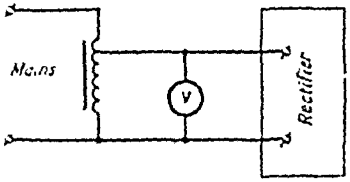


Fig. 153. Primary voltage adjustment by means of autotransformer ЛАТР

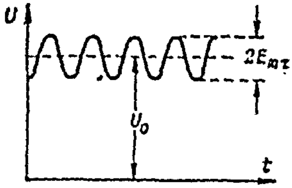


Fig. 154. Rectifier output voltage with ripple

the insulation is tripped off so that a brush could come in contact with the winding, varying the output voltage in accordance with the brush position.

MEASURING RIPPLE VOLTAGE AND LOAD CHARACTERISTIC

All rectifiers irrespective of the number of phases (half-wave, full-wave, etc.) produce a constant voltage on which ripples are superimposed as illustrated in Fig. 154. In this diagram U_0 is the constant component of the rectified voltage and E_{mr} is the amplitude of the ripple component. The magnitude of alternating voltage at a rectifier output is called ripple. The ripple frequency F_r depends on the number of rectifier phases:

$$F_r = F_m m$$

where F_m — frequency of the power supply mains

m — number of phases (which may be 2; 3 or 6).

The higher the ripple frequency, the easier is it filtered. The ripple magnitude is estimated by ripple factor K which is a ratio of the amplitude of the alternating voltage to the rectified voltage and is expressed in per cent:

$$K = \frac{E_{mr}}{U_0} \times 100\%$$

The permissible ripple factor for each rectifier is specified in instructions or specifications.

A diagram of ripple voltage measurement is represented in Fig. 155. As a rule the rectifier is connected to the a.c. mains by means of an autotransformer. The rated supply voltage at the rectifier input is measured by voltmeter V_1. Another voltmeter (V_2) is connected at the filter output in parallel with the load resistance R_L which has

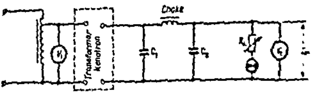


Fig 155 Measurement of ripple voltage

a milliammeter or ammeter connected in series (depending on the magnitude of the rectified current), and a tube voltmeter. Load current measurements are required for plotting the rectifier current-voltage characteristic. The required current value is set with the aid of the variable load R_L, whereas the rectifier *voltage* value at the rectifier output (under load) is read out from the voltmeter V_2 scale.

It is practicable to use rheostats as load R_L. The ripple voltage is measured with an a.c. voltmeter the internal resistance of which is larger as compared to the input filter capacitor. Such meters are tube voltmeters and oscilloscopes. A tube voltmeter type BKC-7 can be employed if the ripple voltage is over 0.2 V. If the rectified voltage is equal to 300 V the ripple percentage may be from [illegible] per cent up. In case of smaller values of the permissible ripple at the filter output, use is made of more sensitive tube voltmeters or oscilloscopes C1-1.

Ripple voltage is [illegible] Fig. 155. The [illegible] should be [illegible] being measured [illegible] should be [illegible] rent values.

The nominal input voltage to the rectifying device U_1 is set by the voltmeter with the aid of the autotransformer, depending on the rating (110; 127 or 220 V). The rectified voltage is measured by the d.c. voltmeter V_2 first setting the load resistance R_L at a level which will ensure that the rectified direct current is equal to a given value I_0, specified in the instructions. Following that the ripple voltage U_r is measured with the aid of a tube voltmeter or oscilloscope, and ripple factor is determined in accordance with the formula

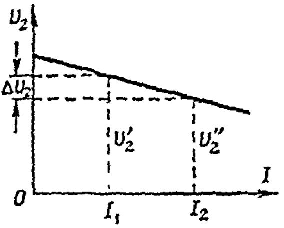


Fig. 156. Typical rectifier load characteristic

$$K_r = \frac{U_r \sqrt{2} \times 100}{U_2} \%$$

where K_r—ripple percentage
U_2—nominal rectified voltage.

Since the tube voltmeter or oscilloscope are graduated in r.m.s. values, the above formula is supplemented with the $\sqrt{2}$ coefficient.

The rectifier load characteristic (or volt-ampere characteristic, as it is sometimes termed) shows the dependence of the rectified voltage across the load resistor on the current flowing through the load resistance R_L; when plotting this characteristic, R_L is varied within a range, corresponding to a given range of current variations.

The diagram for plotting load characteristics is the same as for ripple measurements, the only difference being that no tube voltmeter or oscilloscope is required. An example of a load characteristic is given in Fig. 156. As seen from the drawing, the output voltage drops slightly with increase in current. This is due to rise of voltage drop across the windings of the power transformer, kenotrons and filter chokes. Within a given range of current variation the load characteristic can be used to determine the rectifier internal resistance, according to equation

$$R_{int} = \frac{U_2' - U_2''}{I_1 - I_2}$$

Electronic and ionic regulated rectifiers. These rectifiers provide a high degree of voltage stability with regulation factors up to 100 or 200. These values signify that in case of the mains voltage variation by 20 per cent the output voltage across the rectifier load will change by 0.1 to 0.2 per cent only (100 to 200 times reduction). Nowadays a great number of regulator circuits are in use.

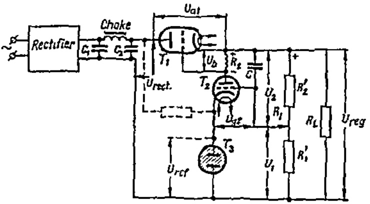


Fig. 157. Simplified circuit diagram of electronic voltage regulator

Regulators are finding ever increasing application in rectifiers installed in commercial radio sets and various radio instruments. Several types of regulated rectifiers are produced by the Soviet industry.

The principle of an electronic regulator can be readily understood with the aid of a simplified diagram represented in Fig. 157. Tube T_1 is the voltage regulator here. Voltage drop U_b of current I_{a2} passing through resistance R_2 is applied between the cathode and grid of this tube; the same current passes through tube T_2 and stabilivolt T_3. The change in anode current of tube T_2 brings about a change in the voltage drop U_b, thus varying the internal resistance of tube T_1. This causes a variation in voltage drop U_{at} across the latter tube.

The voltage across the load U_{reg} is determined as the difference of the rectified voltage U_{rec} and the voltage drop across tube T_1, i.e. $U_{reg} = U_{rec} - U_{at}$. This expres-

sion shows that the regulated output voltage is always less than that at the rectifier filter output.

The tube T_2 is a d.c. amplifier, tube T_3 (gas-filled stabilivolt) is a voltage standard serving as a reference level for the regulated output voltage. The stabilivolt maintains a constant voltage under variations of the current passing through it from 5 to 30 mA.

The voltage U_{g2} between the grid and the cathode of the amplifier tube T_2 is equal to the difference between voltages U_1 and U_{ref}. Voltage U_1 on the slider of potentiometer R_1 is equal to

$$U_1 = U_{reg} \frac{R_1'}{R_1' + R_2'}$$

then

$$U_{g2} = U_1 - U_{ref} = \frac{U_{reg} R_1'}{R_1' + R_2'} - U_{ref}$$

Variations of the mains voltage or load current will result in a change of voltage U_1 and a corresponding change in voltage U_{g2}. The internal resistance of the tube T_1 will change so that the voltage at the rectifier output will remain almost invariable.

In case of large load currents, tube T_1 is composed of a number of tubes of the same type (as many as required for the current) connected in parallel. The output voltage regulator is adjusted by proper positioning the slider of potentiometer R_1 which changes the voltages U_1 and U_{g2}. The total value of resistances R_1' and R_2' are selected so as to make the current passing through the circuit much less than the load current. Capacitor C connected to the grid of tube T_2 in parallel with resistance R_2' serves to remove spurious oscillation in the circuit and to reduce ripples in output voltage.

In this case the ripple voltage is applied to the grid of tube T_2 and ripples at the regulator output are greatly reduced. The smoothing action of the regulator is to a great extent dependent on the amplification factor of tube T_2 and values of C and R_1'. Therefore pentodes with amplification factors of 100 and more are usually employed as amplifying or regulating tubes.

39. Assembly, Adjustment and Testing of Low-Frequency Amplifier

The operation of a low-frequency amplifier is characterized by the following principal parameters: amplification factor; frequency, phase and amplitude characteristics, permissible value of non-linear distortion, inherent noise and hum level; spurious oscillation and input voltage value (sensitivity of amplifier).

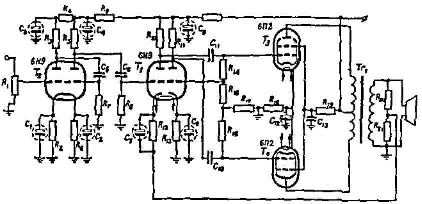


Fig. 158. A low-frequency amplifier circuit

The circuit diagram of a low-frequency amplifier (without the rectifier) is represented in Fig. 158. The circuit has three voltage amplification stages. The left part of tube T_2 functions as a third amplification stage; the right-hand part of this tube shifts the voltage phase by 180°

The amplification circuit of tube T_2 is of the so-called phase-inverting type. Instead of this circuit a transformer stage with a centre tap on the transformer secondary winding can be used to produce two out-of-phase voltages of equal amplitudes on the grids of the output stage tubes. In the amplifier under consideration there is a negative feedback involving the output and inverting stages

To exclude stray couplings, it is necessary to eliminate parallel and close arrangement of wires of grid circuits of input tubes and anode circuits of output tubes; if neces-

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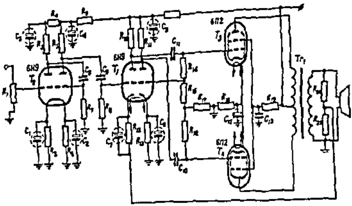


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To exclude stray couplings, it is necessary to eliminate parallel and close arrangement of wires of grid circuits of input tubes and anode circuits of output tubes; if neces

fier load by the volume control. Following this, output voltage variations as a function of input frequency are determined.

To check hum level, disconnect the audio oscillator and short-circuit the l.f. amplifier input. Check that the output voltage is not in excess of that specified in the instructions. The principal reasons for excessive hum level of a l.f. amplifier are faulty tubes or a defective power supply filter.

The tone control is checked for operation by means of similar measurements in various positions of the control. The output voltage values should be within a specified range. Departure from these values is indicative, in the first place, of faulty load and tone control circuits.

In piece production, when experimental articles are manufactured, the adjustment of a l.f. amplifier becomes more complicated, since in addition to the above checks it is necessary to select operating conditions for the tubes, the values of resistors and capacitors, circuit inductivity and feedback coupling which are to be adjusted finally and are not to be changed in operation.

40. Radio Receiving Equipment Assembly and Adjustment

Modern radio receivers employ straight amplification, superheterodyne and in certain cases superregenerative techniques.

In straight amplification receivers high-fidelity reception involves a considerable complication of the circuit, increase in overall dimensions, weight and cost. This is particularly true of short-wave reception.

Superregenerative receivers feature comparatively simple circuits, small size, and sufficiently large amplification, but their disadvantages include low selectivity, high noise level and spurious radiation.

The superheterodyne circuit ensures high sensitivity with simple receiver designs. At the present state of radio engineering art superheterodyne receivers are the most extensively used. For this reason this section will deal with a description of the processes of assembly, adjustment and testing of this type of receivers.

ASSEMBLY OF SUPERHETERODYNE RECEIVERS

Superheterodyne reception technique is based on the conversion of input signal frequency f_s into another so-called intermediate frequency f_i on which the major part of signal amplification is performed. The intermediate frequency is produced in a converter, consisting of a heterodyne and a mixer, and the intermediate frequency is derived on the tuned circuits of the latter. The major part of amplification takes place in the intermediate frequency amplifier.

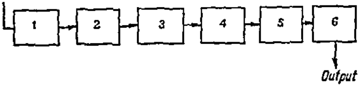


Fig. 160. Block diagram of a superheterodyne receiver

The intermediate frequency is constant in most receivers, hence the intermediate frequency amplifier can be fixed tuned.

The intermediate frequency voltage, amplified to a required level, is subsequently detected, producing a low-frequency voltage which is amplified and applied to a loudspeaker, cathode-ray tube or other output device depending on receiver type. The block diagram of a superheterodyne receiver (Fig. 160) contains input circuit *1*, high-frequency amplifier *2*, frequency converter *3*, intermediate frequency amplifier *4*, detector *5* and low-frequency amplifier *6*.

There are different types and designs of receivers with various circuits, elements and units. The layout of parts and assemblies on the chassis or base frame can also vary, however the mechanical arrangement (assembly) of parts and units, i.e. their fitting to the chassis or base frame, remains unvariable which is to a great extent due to the unification of parts and units widely adopted by Soviet radio engineering plants.

As to design receivers are fabricated on a common chassis with built-in units. The electric connections (wiring) are made in compliance with rules discussed earlier.

Assembly of radio receiver rectifier. A.c. mains operated receivers employ tube or semiconductor rectifiers. In commercial receiving equipment rectifiers are assembled on a common chassis, sometimes as separate units. The mains transformers are generally designed for operation from the 110; 127 and 220 V mains. The transformers are of diversified design. In some designs the panel and block for commutating the transformer windings in case of connection to the 110; 127 and 220 V mains and the kenotron tube socket are located on the transformer itself.

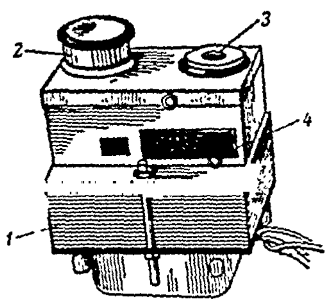


Fig. 161. Power transfromer (general view)
1—magnetic core; 2—winding change-over switch; 3—kenotron tube socket; 4—safety fuse base

The general view of a 75 to 80 W power transformer is illustrated in Fig. 161. Fig. 162*a* represents the "semi-wiring" diagram of this transformer with the winding

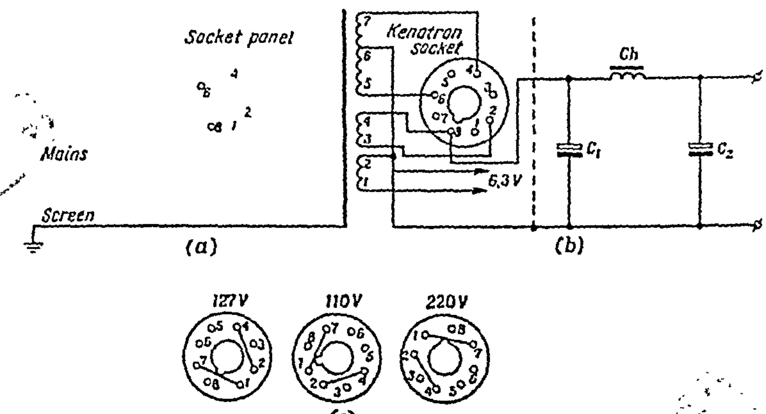


Fig. 162. Rectifier wiring diagram
a—transformer circuit; *b*—filter circuit; *c*—block position in the sw[illegible] (three top views on panel)

commutation, fuse and kenotron tube socket. The the winding commutator block is furnished w

grooves for the locking lug; therefore the block can be fitted into the panel in three different positions corresponding to the three basic mains voltages.

The diagram of an inductive-capacitive smoothing filter with all the elements attached directly to the chassis is represented in Fig. 162*b*. The tube socket, fuse and block panel are secured to the transformer casing which after wiring is fitted to the core together with the lower cover

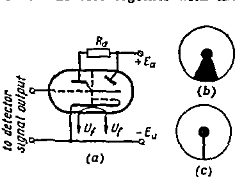


Fig. 163. Cathode-ray tuning indicator
a—circuit diagram; *b*— indicator screen in the absence of tuning; *c*—indicator screen under accurate tuning (darkened sector narrowed)

and secured by means of studs and nuts The position of the block in the commutator panel is shown in Fig. 162*c*.

Sometimes it is necessary to insulate the rectifier "minus" terminal from the chassis to obtain a constant grid bias. In such cases the body of respective filter capacitors is insulated from the chassis by means of a special spacer or washer made of an insulating material.

Wiring the cathode-ray tuning indicator. Cathode-ray tuning indicators are widely used in radio equipment. They provide a visual means of accurate tuning of the receiver to the input signal frequency. A detailed description of the design and principle of operation of this device is given below.

The circuit diagram of a tuning indicator is presented in Fig. 163*a*. If no voltage from the detector stage is applied to the triode grid, a negative voltage will be built up (with respect to the screen voltage) on the anode and cont

electrode. As a result, electrons from the common cathode will not flow to the screen in the vicinity of the control electrode and hence a shadow sector will be observed on the screen (Fig. 163*b*).

When a negative voltage from the detector is applied to the circuit input (Fig. 163*a*) the triode is cut off and its anode voltage increases resulting in a decrease in negative voltage on the control electrode with respect to the screen. In this case electrons from the cathode flow to the screen

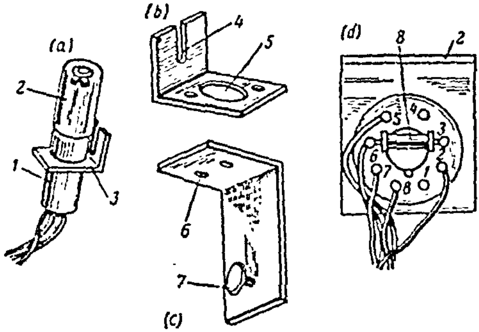


Fig. 164. Tuning indicator ("magic eye")
a—general view of indicator and bracket; *b*—bracket for tube socket; *c*—bracket fastening angle bar; *d*—indicator tube wiring

passing close to the control electrode as well, which brings about a narrowing of the shadow sector (Fig. 163*c*).

The tuning indicator is located in the apparatus so that its screen is visible from the cabinet face panel (a hole is provided for this purpose). The indicator tube socket is attached to a bracket which can be installed in different places: on the dial system, cabinet or chassis. The length of wires running from the tube socket should allow the tube to be fitted in the bracket. As seen in Fig. 163*a*, five wires run to the tube socket. The resistor R_a is connected directly to the third and sixth lugs of the tube socket.

The brackets can be of various design. A bracket for a typical receiver set is represented in Fig. 164. The tube socket *2* is attached to bracket *3* with the aid of cap *1*. Hole *5* is for the tube socket. Resistor *8* is soldered directly to the socket. The bracket is provided with slot *4* which

accommodates the screw of angle bar 7 fastened from the inner side of the cabinet. The bracket is screwed to the angle bar, secured on the cabinet with the aid of screws through holes 6. Prior to removing the receiver from the cabinet or prior to replacing the tube, the bracket with the tube should be dismantled.

Wiring intermediate frequency amplifier. Commercial superheterodyne receivers employ from one to three i.f. am-

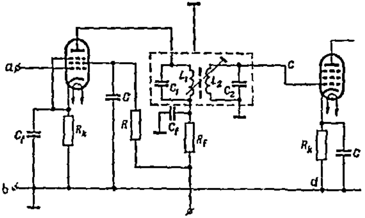


Fig. 165. Circuit diagram of amplifier stage with a double-tuned filter

plifier stages. The amplifier tube plate circuits usually consist of double-tuned i.f. filters. The circuit diagram of an i.f. amplifier stage is illustrated in Fig. 165. The filter with inductive coupling between tuned circuits is outlined by a dashed line. The filter consists of two induction coils L_1 and L_2 and capacitors C_1 and C_2 connected in parallel with the coils. The circuits are tuned with the aid of carbonyl cores type СЦР. The decoupling (or blocking) filter elements C_f and R_f in commercial receivers with one or two i.f. amplification stages are sometimes excluded.

The stage input is designated by letters *a-b* and the output—by letters *c-d*. Resistor R_k and capacitor C comprise the self-bias circuit. The negative bias voltage is due to anode and screen grid current passing through the resistor.

Resistor R is provided to reduce d.c. voltage applied to the screen grid and capacitor C serves to reduce ripple voltage from the rectifier and bypass i.f. current.

Commercial receiver sets employ filters consisting of one, two, three and four circuits. In addition, various combinations of these filters are employed to produce a resultant frequency response of the amplifier of a pattern as close to rectangular as possible.

The filters are assembled on a separate work bench. First of all the induction coils of the circuits are installed. The coils are inserted into one half of a shell-type carbonyl core type СБ-1а whose central hole is not threaded. Next the other (threaded) half of the core is assembled and the leads are fitted with linoxyn or pvc tubing.

The leads are fitted in the slots. The core assembly (with the coil inside) is squeezed from the butt-ends, its circumference is coated with polystyrene varnish or glue and is wrapped with a thin silk fabric. After the polystyrene varnish has hardened, the clamping force is removed and a core is obtained with two firmly fitting halves.

Trimming is achieved with the aid of a СЦР-type core provided with a slit at one end to accommodate a screw driver tip. The core assembly is coated with polystyrene varnish or glue and fitted into a frame in which it is fastened with glue БФ-4. Next a cylindrical calibrated molded powder plastic spacer is inserted into the frame and then the second core assembly. The spacer ensures proper spacing between core assemblies.

After fitting, the coils and capacitors are wired to frame lugs in compliance with the wiring diagram. The completed filters are attached to the chassis by means of screws or clips. The lugs or leads of the coils are passed through holes into the chassis underside where they are soldered in accordance with the wiring diagram or model.

Usually commercial and special-purpose receivers are multistage, particularly, *wide-band amplifiers, featuring* a low amplification factor per stage. Spurious feedback may result from irrational layout of the components and awkward wiring. Stray feedback can be the cause of self-excitation of the amplifier or distortion of its frequency response.

These troubles may also occur in narrow-band i.f. amplifiers with comparatively large amplification factors and a small number of stages. In narrow-band amplifiers with the intermediate frequency not exceeding 1 Mc/s stray feedback coupling can heavily distort the frequency response pattern. Since the tuned circuits of all i.f. amplifiers are shielded, the principal source of stray feedback coupling is the electric and magnetic coupling between wires and radio components.

An important role in this respect is assigned to the points (places) of connection of the wires to the chassis (grounding



Fig. 166. Methods of capacitor attachment
a—wrong; b—right

points). Until recently it was a widespread belief that all grounding leads should be connected in one place on the chassis, i.e. in one point, and this grounding point is to be specially selected. But, it was realized that an error might occur in choosing the grounding points. The best method of wiring consists in grounding each part with the shortest wire possible. Of much importance is a reliable contact with the chassis or with common grounding bar. Good results are obtained by grounding the parts by conductors soldered to special "cuts" in the chassis.

Resistors and capacitors should be arranged so as to result in minimum coupling between elements of the plate and grid circuits of an amplifier stage. This principle of wiring and location of parts is of particular importance when applied to wide-band i.f. amplifiers.

Let us consider the procedure of wiring capacitors and filters. The method of wiring of a capacitor provided with lugs (one of which is to be grounded) is illustrated in Fig. 166. At frequencies of the order of scores of Mc/s an erroneous wiring of the capacitor is fraught with troublesome consequences, since the inductance of the wiring conductors will

be in series with the capacitor. 10-cm length of wire has 0.1 μH inductance and at high frequencies it offers a considerable impedance. For the same reason the inductive reactance of the cathode circuit will also increase causing degra-

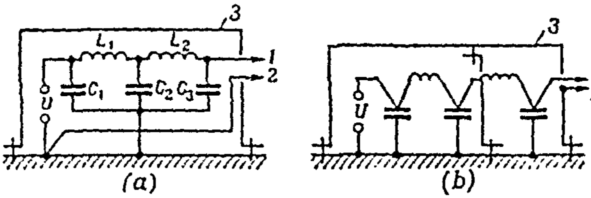


Fig. 167. Filter wiring
a—wrong; *b*—right; *1* and *2*—output leads; *3*—screen

dation of the amplifier tube operation, particularly in wide-band i.f. amplifiers. Examples of proper and irrational wiring of filters are illustrated in Fig. 167.

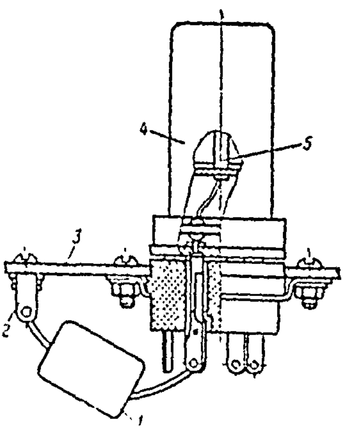


Fig. 168. Circuit of tube cathode with partial representation of wiring

An illustration of a circuit of cathode *5* of tube *4* with part of the wiring is given in Fig. 168. As seen in the drawing, the length of the cathode lead from the cathode to the chassis is considerable. Therefore in the u.h.f. range ceramic blocking capacitors *1* are used and these are directly attached to the chassis *3* with the aid of lugs *2* thus achieving the required grounding. On still higher frequencies the blocking capacitance is provided in the tube socket itself, thus eliminating the effects of the capacitor lead inductances.

Various circuit patterns of decoupling filters are used in wide-band i.f. amplifiers. Three wiring diagrams for plate and screen grid circuits are illustrated in Fig. 169. Blocking filters are also employed in filament circuits.

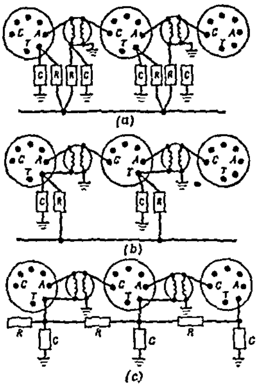


Fig. 169. Wiring of anode and screen grid circuits of a three-stage broad-band amplifier with miniature tubes

a—decoupling circuits in anodes and screen grids; b—with one common decoupling filter for anode and screen grid (decoupling filters in parallel); c—same, decoupling filters in series

High-frequency unit assembly. In modern radio equipment h.f. amplifiers with all the constituent parts and converters are assembled in one unit, designated a high-frequency unit. This design has the following advantages: this unit is assembled and wired separately from the receiver; it can be tuned and adjusted on a special test bench irrespective of the rest of the receiver, which speeds up the assembly, improving the quality and reducing the cost in mass production of the equipment.

In the course of final assembly and wiring, the high-frequency unit is fitted on the receiver chassis, fastened and soldered to the receiver circuit.

Soviet industry manufactures a series of first-class receiver sets in which the high-frequency elements are assembled in one unit. An example can be furnished by a combination set consisting of a TV, radio receiver and a universal record player.

The TV set insures high-fidelity reception in any of the 12 available TV bands. Its high-frequency unit is a superheterodyne single-channel circuit.

The radio receiver set incorporates five subranges: long-wave, medium-wave, two short-wave and one u.h.f.-FM range. All the commutations are achieved by a pushbutton switch. The chassis of the set has a common frame with a number of functional units mounted on it, viz: the scanning system, TV control panels, pushbutton switch, u.h.f. units and others.

In the course of wiring of the receiver the h.f. unit circuits are soldered to the common circuit. The triple-ganged variable capacitor is mounted above the high-frequency unit on three rubber shock absorbers.

The tuning is done manually from the side of the receiver through a system of pulleys and cables due to which a smooth retarded rotation of the capacitor rotor axle and simultaneous movement of the indicator along the dial are obtained. The circuit coils of the long- and medium-wave stages are wound on plastic formers enclosed in small-size carbonyl shell-type cores СБ-1а 12 mm in diameter.

Fine tuning within each range is obtained by means of a variable capacitor; switching from one subrange to another is effected by switching the inductance coils of each circuit. The band selectors should be reliable in operation; they should have a small direct capacitance and high dielectric resistance between adjacent contacts. The band selector contact resistance is in the range of hundredths of an ohm.

SUPERHETERODYNE RECEIVER ADJUSTMENT

Most modern radio and TV receiver sets are superheterodyne types which enables high selectivity to be obtained simultaneously with high sensitivity and undistorted signal reproduction; in addition, superheterodyne receivers are easily tuned to a broadcasting station. In series and mass

product
dyne re
ments,
and tuning of the receiver as a whole.

Galvanic check-up of circuits prior to adjustment and tuning is performed to detect faults of assembly and wiring and check the resistance values of individual circuits for compliance with the calibrating chart data.

In large-scale and mass production the galvanic check-up of receiver circuits and testing of the voltages are carried out with the aid of semiautomatic and automatic measuring instruments, after which the tube operating conditions are checked for correspondence to the calibrating chart data. The measurements are taken between tube electrodes and certain

[illegible]

fier output d.c. voltage are checked. Following that the operating conditions of the tubes in the output stage, l.f. amplifier stages, tuning indicator, i.f. amplifier stages, converter (also of heterodyne tube, if it is a separate one) are examined and last of all the operating conditions of the h.f. amplifier stages are measured.

Adjustment of detector and automatic gain control circuit. An amplitude detector (generally a diode-type in superheterodyne receivers) is provided to separate a low-frequency amplitude-modulated voltage from high-frequency amplitude-modulated oscillations at the intermediate-frequency amplifier output. Due to the diode detector, distortions are at a minimum and automatic gain control (a.g.c.) is easily achieved. The principal characteristics of the detector are the voltage transfer ratio and non-linear distortion factor.

For the reception of frequency-modulated (FM) signals the frequency detector and amplitude limiter circuits should be tuned. The adjustment is achieved with the aid of frequency response meters (containing frequency-modulated oscillators and oscilloscopes) and a frequency calibrator. The oscillator output is connected to the limiter control grid, and the oscilloscope input—to the frequency detector output (Fig. 170*a*).

A pattern illustrated in Fig. 170*b* will be displayed on the oscilloscope screen. Adjusting the limiter and frequency detector circuits, the curve humps are made symmetrical and the curve made to intersect the zero line at the intermediate frequency.

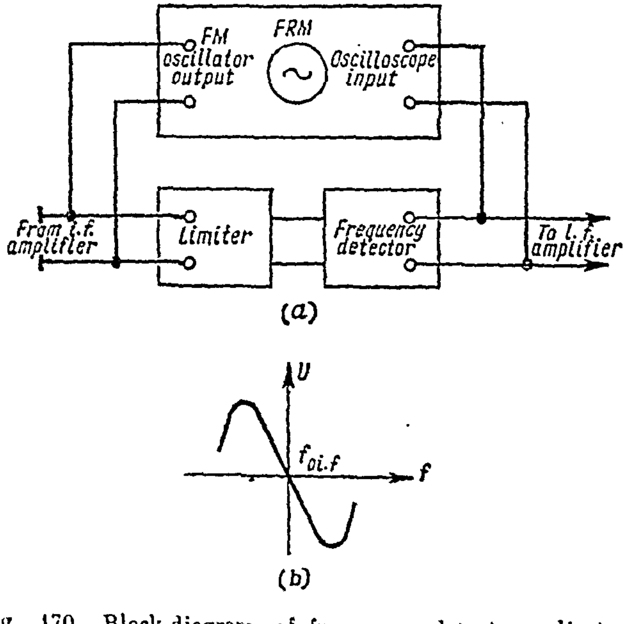


Fig. 170. Block-diagram of frequency detector adjustment (*a*) and frequency response (*b*)

Adjustment of i.f. amplifier. Prior to adjustment of the i.f. amplifier check the operating conditions of the i.f. amplifier and converter or mixer tubes, if this check has not already been done. The i.f. amplifier is to be tuned after adjustment of the l.f. amplifier and detector. In tuning the circuits the a.g.c. must be turned off since a.g.c. tends to make the tuning less sensitive. This can be achieved either by switching off the a.g.c. circuit or by tuning the i.f. amplifier circuits with a voltage drop across the a.g.c. detector not more than the delay voltage magnitude (1.5 V).

In the latter case the a.g.c. detector will be cut off and any influence of the a.g.c. will be eliminated. If the a.g.c. detector is connected to an intermediate circuit, the volume control should be set after tuning the last stage of the i.f. amplifier.

The i.f. amplifier adjustment procedure is as follows: plug in the receiver jack with the cable connecting the output transformer secondary with the loudspeaker equivalent and output meter. Following that put the tone control into positions corresponding to the steep slope of higher and lower audio frequencies and the i.f. amplifier band control into the "narrow band" position. The band selector switch should be in the long-wave position.

The next step includes a stage-by-stage adjustment of the i.f. amplifier filters following which the i.f. amplifier is to be tuned as a whole.

In conclusion, the amplification factor, passband, precision of tuning and attenuation of adjacent channels are measured.

High-frequency unit adjustment. The high-frequency unit includes the input circuits, high-frequency amplifier, frequency converter (or mixer), heterodyne, and the filter blocking intermediate frequency signals.

Prior to adjustment of the h.f. unit mechanically couple the multiganged capacitor unit with the receiver vernier-dial installation. This is necessary to match the position of the indicator on the receiver dial with the angle of rotation of the rotors of the multiganged capacitor.

Following that check heterodyne generation in all subranges with the aid of a tube voltmeter.

The following step of adjustment of a h.f. unit includes the tuning of the band-elimination and i.f. cut-off filter.

Next tune the input circuits and the h.f. amplifier circuits. These circuits are tuned by trimmers to maximum receiver output voltage.

Subsequently tune the receiver (by the tuning dial) and a standard-signal generator to the lowest tracking frequency.

Pass over to the highest tracking frequency and tune the circuits with the aid of trimmers to maximum output voltage.

41. Adjustment of Radio Transmitting Equipment

The transmitter generates high-frequency current which is passed to the antenna for radiation into space. The transmission of audio frequency oscillations is achieved by variating the high-frequency current in compliance with the transmitted signal pattern. This variation is known as *modulation*. The transmitter range depends on the power of oscillations radiated. According to radiated power all transmitters are divided into three groups: low-power transmitters (up to 100 W), medium- (from 100 to 1,000 W) and high-power (over 1,000 W).

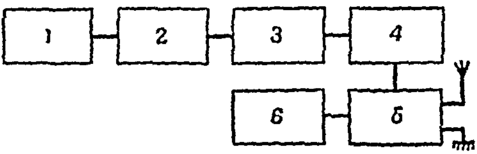


Fig. 171. Transmitter block-diagram

Fig. 171 illustrates the block-diagram of a transmitter consisting of master oscillator *1*, buffer stage *2*, multiplier stage *3*, high-frequency amplifier *4*, power amplifier *5* and modulator *6*.

Depending on production scale two methods of transmitter adjustment are employed. According to the first method each stage (unit, circuit) of the transmitter is thoroughly adjusted until the required parameters have been obtained. By the second method each stage is adjusted roughly (until operative), the final adjustment being carried out on the completely assembled transmitter.

The first method (in which all defects of each stage are detected) is employed for mass and batch production, the second—for piece and small-scale production, as well as for the repair and maintenance of transmitters. In mass and batch production all stages are tuned simultaneously, in piece production they are tuned one by one. In the successive method of adjustment the transmitter stages should be tuned, starting with the input and ending with the

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In their designation transmitters [illegible] communication (for various communication lines), broadcasting and special-purpose. Communication transmitters are the most widely used, and their adjustment is discussed in this section. The adjustment of special-purpose transmitters despite certain specific features is almost the same as for communication transmitters.

MASTER OSCILLATOR ADJUSTMENT

The master oscillator generates high-frequency oscillations in a definite frequency range. In the process of transmitter tuning the frequency of the master oscillator is adjusted whereas the other stages are tuned to resonance at this frequency. Thus the operation of the entire transmitter is dependent on the quality of operation of the master oscillator.

Frequency deviation from its nominal value constitutes the *main index of operation of the master oscillator*. The deviation is a sum of the frequency dial setting error and frequency variations due to destabilizing factors. The effect of destabilizing factors on frequency deviation is dependent on the design of the master oscillator and other transmitter elements connected with it The effect of fluctuations of the [illegible] rectifier unit. The barretter is often used for tube filament current regulation.

A filament current regulated circuit using a barretter is represented in Fig. 172. Current passing through the barretter changes with variations of the supply voltage. The current change results in a change of barretter resistance R and a corresponding change of voltage drop U_d across it due to which tube filament voltage U_f remains constant.

Frequency deviations of the master oscillator due to variations in supply voltage and self-heating of the tubes and other components is checked on each master oscillator. The permissible values of total frequency deviation from the nominal value and frequency variations due to each

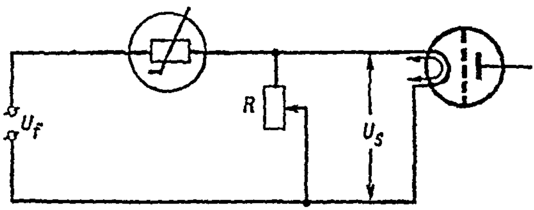


Fig. 172. Filament voltage regulation with the use of a barretter

destabilizing factor separately are listed for each transmitter design in the technical specifications.

A simplified circuit of a master oscillator is illustrated in Fig. 173. The diagram refers to a continuously tuned

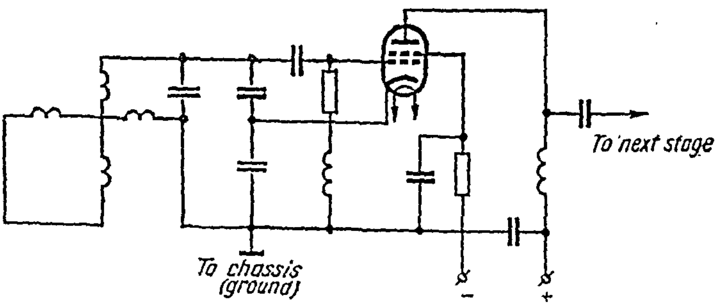


Fig. 173. Simplified circuit of master oscillator

oscillator whose adjustment will be discussed in subsequent sections. The master oscillator may also be fixed tuned to one or several precise fixed frequencies. In the latter case the master oscillator adjustment procedure will be simplified to a large extent and therefore is not worth discussing.

Sometimes frequency stability is increased with the aid of a variometer with a rotor in the form of an odd-shaped

short-circuited turn. Such a variometer has a small tuning range (frequency tuning range exceeding 2.5 to 3 times is very difficult to obtain) and for this reason the master oscillator range is divided into several subranges.

The method of adjustment of the master oscillator will be discussed as applied to the continuously tuned wide-band oscillator with one frequency range. Before delivery to the adjustment station, all units are checked for proper electrical connections. The circuits are checked for continuity, the wiring—for proper connections and the resistances—for correct values. This is the so-called galvanic test performed by means of a usual ohmmeter or tester successively circuit by circuit. In mass production the check is carried out on special semiautomatic test beds which make it possible to check all circuits and to detect all faults.

The master oscillator adjustment procedure incorporates the following principle operations which must follow in strict succession.

1. Checking the electric circuits for continuity.
2. Range matching.
3. Thermal ageing.
4. Adjustment of the effect of changes in ambient temperature (thermal compensation).
5. Self-heating test.
6. Checking for external mechanical effects.
7. Checking for effects of supply voltage fluctuations.
8. Dial calibration.

Diverse measuring apparatus and equipment are used in the adjustment of a master oscillator, including test beds for mechanical checks (effect of mechanical impacts), thermal chamber, dial calibration stand, supply sources, etc.

The succession of operations and methods of their performance are discussed below.

Checking electric circuits for continuity. Prior to checking fit the oscillator tube to the master oscillator, connect the master oscillator to its power supply unit, switch on the filament supply and, after a certain time delay, high voltage. Check the voltages and currents for compliance with the calibrating chart. The measurements should be made at nominal mains voltage. Discrepancies between values meas-

ured and calibrating chart data exceeding ±5 per cent are indicative of a fault.

Check for variations in anode current over the tuning range. Anode current should change smoothly when turning the tuning control. "Jumps" of anode current indicate spurious generation (generation at a frequency other than specified) or of a stray power-drain. Absence of current variations during tuning can be an indication of absence of oscillations.

Range matching. This operation implies a selection of circuit elements (inductance and capacitance values) in

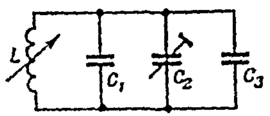


Fig. 174. Schematic representation of master oscillator tuned circuit

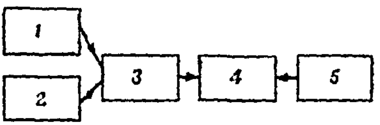


Fig. 175. Block diagram of instruments set-up for measurement of master oscillator frequency

such a way that the master oscillator frequency range should correspond to the change of the variometer inductance. To carry out this adjustment, set trimmer C_2 of the master oscillator circuit (Fig. 174) in a middle position, since this trimmer is intended for oscillator frequency adjustment in operation. Connect the master oscillator to its power supply, switching on the filament circuit and, after some delay, the high-voltage circuit. Connect a heterodyne wavemeter to the circuit. Connect an "antenna" (a conductor coiled into several turns to form a ring) to the wavemeter input. Sufficient coupling is usually achieved by placing the ring in close proximity to the master oscillator tuned circuit.

Measuring the maximum and minimum frequency of the master oscillator range by the dial of the heterodyne wavemeter and turning the oscillator tuning control knob until zero beats are obtained, determine the position of the tuning control knob, corresponding to the maximum and minimum frequencies. The range should be matched so that the distance from the extreme positions of the tuning control knob to the positions corresponding to the beginning and

end of the range is the same. This operation is performed by selecting the required capacitance of the circuit capacitors (Fig. 174).

Adjustment of the ambient temperature. The block-diagram for measuring the master oscillator frequency is represented in Fig. 175. The signal of a standard frequency source (crystal oscillator *1*) and the signal of master oscillator *2* are applied to the inputs of mixer *3*. To obtain audible beats at the mixer output, it is necessary to intentionally detune the master oscillator respective to the standard by a certain audio frequency. The frequency difference from the mixer output is applied to the horizontal deflection plates of oscilloscope *4*, whereas a frequency from audio oscillator *5* is applied to its vertical deflection plates.

If two voltages of equal frequency are applied to both pairs of the oscilloscope deflection plates, the simplest Lissajous figure (ellipse) will be observed on the oscilloscope screen. Variations of the master oscillator frequency are read out from the frequency readings on the audio generator maintaining the ellipse on the oscilloscope screen constant.

An approximate sequence of operations will be as follows: place the master oscillator into the thermal chamber and connect to its power supply. Switch on the filament supply and after some delay, high-voltage supply. Tune the master oscillator so that its frequency differs from that of a crystal oscillator by an audio frequency (say 1,000 c/s). Adjusting the audio generator frequency obtain an ellipse on the oscilloscope screen. In this position the audio generator frequency is equal to the difference in frequencies between the master and crystal oscillators. Register the audio generator frequency and the initial temperature in the chamber. Switch on the thermal chamber heating, putting the automatic regulator to a preset temperature. Usually the chamber is heated to 50-70°C.

Maintaining the ellipse on the oscilloscope screen constant by tuning the audio generator take frequency readings of the generator frequency at equal time intervals (15 to 30 min). Measurements are taken until the master oscillator frequency becomes constant. In most cases it takes 3 to 4 hrs to achieve a constant frequency. Following that switch

off the chamber and cool it to the ambient temperature without taking out the master oscillator.

For adequate frequency stability transmitters the frequency temperature coefficient must generally be in the range of $\pm 5 \times 10^{-6}$. If the required frequency temperature coefficient (FTC) cannot be obtained, it is an indication of insufficient thermal compensation. In this case capacitors of an opposite sign of capacitance temperature coefficient (CTC) should be selected and some of the capacitors of one group should be replaced with capacitors of another thermal group, retaining the total value of the circuit capacitance invariable so as not to disturb range matching.

It should be noted that for a positive change of frequency temperature coefficient the capacitance of the group of capacitors of negative CTC should be increased and respectively the capacitance of the group of capacitors of positive CTC decreased and vice versa. A successive approximation method is employed for thermal compensation matching, repeating the procedure several times, until a frequency temperature coefficient within required limits is achieved.

Self-heating check. One of the destabilization factors is frequency variation due to heating of the tube and the master oscillator elements by the current passing through them. It is essential that this frequency change does not exceed a permissible value for a given type of master oscillator.

Depending on the type of master oscillator, check the effect of self-heating for the first 5 min, 30 min or one hour. Take frequency readings in accordance with the diagram of Fig. 175. To this end, connect the master oscillator to the power supply, switch on the filament heating circuit, then the high-voltage circuit and measure the audio generator frequency, using the method described above, first every 1 to 3 min, then, as the changes in oscillator frequency become smaller, at larger intervals. Record the audio generator frequencies and the time in a table and plot a graph of oscillator frequency deviation.

Checking for external mechanical effects. Depending on the transmitter operating conditions the master oscillator is put through mechanical tests (impacts, vibrations, shaking) to check for frequency stability under these con-

ditions. Mechanical stresses are imparted to the entire unit in which the master oscillator is arranged. The unit is fastened on the test bed and the power supply connected to the oscillator. The filament supply circuit is switched on, then the high voltage, and frequency readings are taken. The master oscillator frequency is set and measured by the audio generator as in previous measurements.

If check-up of frequency stability under vibrations is not specified, the unit is tested on the bed with the master oscillator power supply switched off. Depending on the transmitter designation and operational requirements, the test is to continue for 1 to 3 hrs. During various mechanical tests of the apparatus, the master oscillator control knob must be reliably locked in position. After the test, the power supply is once again switched on and readings of the audio generator frequency are taken.

Checking the effects of supply voltage fluctuations. This check is either carried out separately or combined with some other test.

After switching on the master oscillator and its heating, the frequency is set and the frequency of the audio generator in accordance with the adopted routine stated above is measured. The mains voltage is increased by 10 per cent and after a 5 min delay the audio generator frequency is changed until the same ellipse is obtained. The change in the audio generator frequency is equal to the change of frequency of the master oscillator. In the same way frequency change due to a 10 per cent reduction in the mains voltage is determined. The five minute delay is required for frequency run-out after changing the mains voltage. This check is commonly carried out in three dial positions: minimum, middle and maximum frequency of the oscillator range.

Generally the tuned circuit of a [illegible] master [illegible]ance of [illegible] short-shortest wave band, gradually passing to the longer ones.

Dial calibration. In most cases the dial is kinematically coupled with the master oscillator fine control knob. Dial

calibration consists in marking graduations on the dial which correspond to a definite frequency of the master oscillator when setting the fine control dial to these graduation marks. The smaller the scale division value and the greater the distance between adjacent divisions, the greater is the resolving power, i.e. the more accurately the required frequency can be set.

The dials (scales) can be simple (divisions on them are generally engraved) and complex (so-called microphotoscales with optical devices). Complex dials are marked with the use of a photoelectric technique on special photograduating devices by the zero-beat method, comparing the master oscillator frequency with a known standard frequency that can be changed in accordance with the frequency division spacings on the dial. At the instance of zero-beats the corresponding graduation line and figure are impressed (photographed) on the dial (to a definite reduced scale). The calibrated dial is suitable for a given master oscillator only, i.e. it is individual and non-interchangeable.

ADJUSTMENT OF BUFFER STAGE

The buffer stage is usually a voltage amplifier operating without grid currents. This stage does not load the master oscillator and in addition protects it from the influence of subsequent, more powerful stages. The buffer stage tuned circuit incorporates a capacitor and variometer whose change of inductivity per degree of rotation should be identical to that of the master oscillator variometer. Thus a simple and reliable coupling of stages is ensured.

A buffer stage can at the same time function as a multiplier stage. In most cases the multiplier separates a second harmonic of the master oscillator frequency. Consequently this stage, depending on operating conditions, is called either a buffer-amplifier or a buffer-doubler. In multirange transmitters the buffer stage can operate in different frequency subranges either as an amplifier or a doubler. The adjustment of the buffer-amplifier is completely identical to the adjustment of the buffer-doubler, except that the latter is tuned to the second harmonic of the master oscillator frequency.

Usually the buffer stage is arranged with the master oscillator as a single unit, but, even if separately arranged, the fine controls of the stages (variometers) are mechanically coupled to a common control knob. Therefore the adjustment of the buffer stage is basically reduced to matching the stages, i.e. obtaining a condition when rotation of the control knob over the entire range in both stages (master oscillator and buffer) corresponds to simultaneous

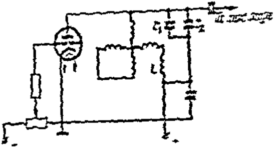


Fig. 176 Simplified circuit of a buffer stage

tuning of the buffer-amplifier to the master oscillator frequency and tuning of the buffer-doubler to the second harmonic of the master oscillator frequency.

A simplified circuit of a buffer stage is illustrated in Fig. 176. For convenience of service adjustment and tuning a low-capacitance variable capacitor C_2 is often connected in parallel with the circuit capacitor C_1. The buffer stage adjustment consists in selecting *capacitor* C_2 and trimming choke L inductance values.

Buffer stage adjustments are carried out with the use of a tube voltmeter, capacitance meter, d.c. milliammeter, dummy load as an equivalent of the following stage and power supplies.

The adjustment is carried out as follows. First connect the dummy load and the voltmeter to the output terminals. The dummy load generally consists of a capacitor and a resistor connected in parallel. Insert the tube into its socket and set the trimmer at the mid-position. Temporarily solder a variable capacitor of the required value in parallel with the trimmer, shunt a certain number of turns of the trimming choke, connect the buffer stage and the

master oscillator to the power supply and finally switch on the filament supply and, after some delay, the high-voltage supply.

Check the voltages and currents for correspondence to the calibrating chart. The permissible divergence of voltages and currents measured at a constant mains voltage with respect to the calibrating chart data must not be over ±10 per cent. A greater divergence is indicative of a defect.

Put the master oscillator control knob in the extreme counterclockwise position corresponding to minimum frequency. Adjust the capacitance of the provisional variable capacitor until a maximum deflection of the voltmeter pointer is observed (i.e. resonance). Following that put the control knob in the extreme clockwise position, corresponding to maximum frequency, and once again obtain resonance tuning with the aid of the same capacitor. If in so doing the capacitance of the capacitor had to be increased, reduce the number of short-circuited turns of the trimming choke; if the capacitance of the capacitor had to be reduced, additionally short-circuit some more turns of the choke.

The adjustment is carried out by the method of successive approximations, repeating the operations until resonance is achieved at both extreme frequencies of the range with one position of the provisional variable capacitor.

As a final check, slowly turning the control knob from stop to stop of the range, make certain that a normal value of the output voltage is maintained over the entire range. Disconnect the temporary soldered variable capacitor and measure its capacitance together with the connecting wires by means of the capacitance meter. Select a capacitor of close capacitance value of a type specified in the diagram and fit it in place. Following that once again check the output voltage by the voltmeter over the entire range and adjust it by the trimmer, if required.

ADJUSTMENT OF VOLTAGE AND AMPLIFICATION

Power is the principal factor governing the number of stages. All intermediate amplifier stages are intended to provide the required excitation (in terms of voltage and power) of the output. Adjustment in the first place

consists in matching the stages, i.e. achieving a state in which all the stages of the transmitter can be tuned in resonance to any frequency of the range. One of the principal points of matching each following stage with the previous one is to ensure the required frequency overlapping of the stages.

Usually the inductive section of a circuit (Fig. 177) consists of a variometer and a trimming choke which serves to select the magnitude of overlapping. The inductance overlapping factor (K_L) is the ratio of maximum to minimum inductance. For a variometer the overlapping factor can be expressed by

$$K_{L\,var} = \frac{L_{max\,var}}{L_{min\,var}}$$

for the circuit inductance

$$K_{L\,c} = \frac{L_{max\,var} + L_{ch}}{L_{min\,var} + L_{ch}}$$

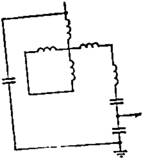


Fig. 177. Schematic representation of an amplifier stage tuned circuit

As seen from the last expression, reduction in inductance of the trimmer choke (in other words, short-circuiting of some turns) increases circuit overlapping.

In the process of adjustment of the amplification stages the variometer tuning limits of each stage are selected so as to provide a simultaneous tuning in at any frequency of the transmitter ranges by turning one control knob only.

The proper setting of the variometers is an essential requirement in the adjustment of all the stages. The frequency of the master oscillator, and hence, the tuning of the rest of the stages are increased when turning the control knob clockwise. Therefore the variometers are set in such a way which will ensure their maximum inductance values with the control knobs in the extreme counterclockwise position (corresponding to the minimum frequency) and minimum inductance values with the knobs turned to the extreme clockwise position. The variometer inductance is made up of the rotor and stator inductances and their mutual

inductance factor:

$$L_{var} = L_r + L_{st} \pm 2M$$

To provide maximum variometer inductance in the extreme counterclockwise position, it is necessary to arrange the rotor respective to the stator so that the direction of their windings, and consequently their currents, coincides. The rotor and the stator are connected either in series or in parallel. In case of series connection the direction of windings in passing from the rotor to the stator and vice versa should remain constant. In case of parallel connection the rotor and stator windings should run in one direction from the common point.

In the course of adjustment of the amplifier stages the resonance tuning of the stages is determined by a minimum in the anode current of a given stage or by a maximum in the grid current of a following stage. In most cases, due to the presence of reactive elements in the grid circuit, the anode current minimum and the grid current maximum are slightly shifted with respect to each other and do not closely coincide.

The resonance tuning accuracy of the penultimate stage is commonly judged by the maximum of grid current of the output stage, since its primary task is to provide the required excitation level. Most often the tuning of intermediate amplifier stages is indicated by an anode current minimum. Monitoring transmitter circuit current is achieved either by installed instruments or with jacks provided for connecting one common instrument to various circuits.

A special test bed equipped with a rectifier, driver and load is used for the adjustment of an amplifier stage. Both dummies and standard transmitter elements (adjusted beforehand) can be used as the test bed equipment. The approximate procedure of adjustment of the amplifier stage can be as follows: set the variometer to maximum inductance at an extreme counterclockwise position of its control knob; connect the unit to the test bed and check the values of the feed voltages for conformity with the calibrating chart. If the adjustment of the preceding stage was carried out with the use of a dummy load, tune the stage grid circuit to maximum grid current (Fig. 178).

Set the variometer to minimum range frequency and then to maximum frequency and check the range tuning limits. In those cases, when the variometer does not ensure tuning to the maximum or minimum frequency it is necessary, by an appropriate selection of trimming choke inductance, to establish a circuit overlapping coefficient which will ensure the required tuning limits. If the variometer tuning limits are adequate and it is only necessary to shift the whole

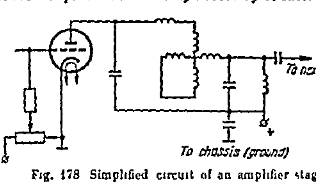


Fig. 178 Simplified circuit of an amplifier stage

tuning range this is done by an appropriate selection of the tuned circuit capacitor or trimming capacitor (if one is provided in the circuit).

The adjustment technique is essentially the same for an intermediate amplifier stage functioning in several subranges. The adjustment begins with the shortest-wave subrange, successively passing over to the longer-wave subranges.

42. Microwave Equipment

ASSEMBLY AND WIRING

In the last decades microwave and position indicating devices have taken up an increasing share in the radio industry output. The principal microwave equipment comprises radio stations designed for detecting and locating objects (targets) in space and communication systems.

Radar equipment consists of individual units interconnected with the aid of multiconductor and radio frequency cables. The units are composed of individual subun-

assemblies which are fitted together at separate working stations. The assembly of this equipment requires special skill and practice. The assembly and wiring of some most specific elements of microwave equipment used in radars are discussed in the following sections.

Waveguide elements. A waveguide duct is a transmission line for microwave energy. Waveguides are made in the form of pipes of circular or rectangular cross section of which rectangular waveguides made of copper or aluminium alloys

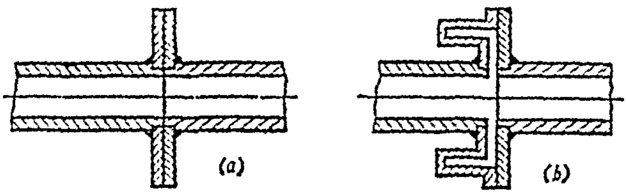


Fig. 179. Flanged waveguide joints
a—with ground-in flanges; *b*—choke-type

are more common. A waveguide assembly (often called plumbing) consists of lengths of various waveguide elements joined by means of flanges. The inner surface of the waveguide is polished to reduce energy losses.

Microwave currents flow in a very thin layer of the waveguide inner surface (the so-called skin-effect), and to reduce the resistance the surface is plated with silver or even gold. The thickness of the plating should exceed 1.5 times the depth of penetration of microwave currents into the metal. The anticorrosive and mechanical properties of silver plating are increased by coating the silver with a thin layer of rhodium (0.1 to 0.2 μ) by means of vacuum evaporation.

To prevent leakage of electromagnetic energy and obtain a good microwave-frequency contact between the waveguides joined together, either ground-in flanges or choke connections are employed. The ground-in flange connection is represented in Fig. 179*a* and the choke connection whose effect is based on the properties of an open quarter-wave and closed half-wave line is represented in Fig. 179*b*.

In addition to straight lengths of waveguide, various waveguide elements are extensively employed, viz: T-junctions in planes H and E (Fig. 180a and c), tapered waveguides to match waveguides of different cross sections

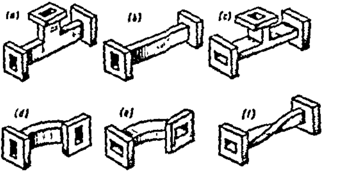


Fig. 180. Waveguide elements
a—H-plane, T-junction; b—tapered waveguide; c—E-plane, T-junction, d—E-plane bend, e—H-plane bend; f—waveguide twist

(Fig. 180b), E- and H-plane bends (Fig. 180d and e), waveguide twists (Fig. 180f), flexible waveguides, etc.

Waveguides are soldered with silver solder alloy grade ПСр-40, using borax as the flux and heating the joints



Fig. 181. High-frequency soldering of waveguide flanges
a—inductor connected to h-f generator, b—inductor under the base

with the aid of an acetylene torch. In series production the heating of waveguides is performed with high-frequency energy utilizing eddy currents.

Two methods of high-frequency soldering are illustrated in Fig. 181. Flange 3 is placed on base 2 of fixture 1

(Fig. 181*a*). Lug *6* is provided for proper positioning of waveguide *5* and for securing it as required. Inductor *7* connected to a high-frequency oscillator is brought up to soldering point *4*. If the inductor cannot be positioned close to the soldering point (on intricate-shape parts), it is brought up to the base (Fig. 181*b*) and heat is transferred to the soldering point from the heated base. Graphite ring *8* prevents the waveguide from welding to the fixing lug.

Aluminium waveguides can be soldered with the use of ultrasonic soldering irons, however a more effective method is soldering such parts in salt baths.

The process of this soldering is as follows. The degreased parts are pressed together in a special fixture with special solder spacers placed between them. Following that, the parts are immersed into a salt bath the temperature of which is 20 to 30°C above the solder melting temperature. To prevent waveguide deformation under thermal shock, the parts assembled in the fixture should be heated beforehand for 5 to 10 min at 500°C.

Individual waveguide sections and the complete waveguide assembly should be matched between themselves and with the antenna. This is achieved with the use of tuning screws or studs in one of the wide walls of the waveguide, and irises in the form of metallic partitions symmetrically arranged across the waveguide and reducing the cross section of the latter. The screws, studs and irises can be considered as pure reactances shunting the waveguide. The waveguide sections supplied to the assembly station should be preliminarily matched between themselves and all the matching elements firmly and accurately soldered.

Magnetron oscillators. Multicavity magnetron oscillators are employed as one of the principal sources of microwave energy in radars.

Modern magnetron oscillators operate in the range of 0.5 to 50 cm waves, at working voltages of 1 to 40 kV and magnetic fields of 600 to 15,000 gausses. In pulsed operation the power output of magnetron oscillators on 1 cm wavelength is up to 100 kW, on a 3 cm wavelength—500 kW and on 10 cm wavelength—over 3,000 kW. Tunable magnetron oscillators have a frequency range of the order of ±5 per cent of the middle frequency.

A [illegible]
[illegible]
[illegible] (Fig. 182).
The cylindrical indirectly heated cathode *3* centred in the anode unit *1* is secured by two cathode leads which are sealed to the glass envelope.

At the cathode butt-ends protective disks *2* are provided which produce an electric field opposing the movement

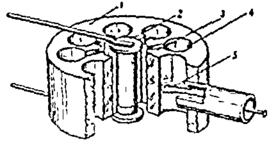


Fig. 182 Schematic cross section of a magnetron

[illegible]

Straps *5* connecting resonators *4* on the butt-ends of the anode unit (every other cavity is strapped together) serve *to separate different modes of oscillation and maintain one* oscillation mode and thus contribute to a stable operation of the magnetron oscillator.

In medium-power magnetron oscillators (above 10 W) ribs are provided on the anode unit outer cylindrical surface to *facilitate heat dissipation.*

The magnetron oscillator is connected to a load via a coupling loop inserted into one cavity. Usually a coaxial jack or waveguide flange comprises the microwave energy output. Microwave energy is generated when the magnetron is placed between the poles of a permanent magnet and the electrons emitted by the cathode move in crossed electric and magnetic fields. The permanent magnets produce a strong magnetic field parallel to the cathode axis.

To increase the magnetic field, the least possible air gap should be left between the permanent magnet poles.

During assembly of the magnetron oscillator it is important to prevent contact of the magnets with any ferromagnetic materials as this will reduce field strength by 20 to 30 oersteds.

Since the magnets possess a very high attracting force, it is necessary to hold the tools (say, screw driver or pliers) firmly enough, otherwise it can be pulled up to the magnet. To prevent this, the magnets can be enclosed in protective aluminium jackets. It is impermissible to strike the magnetic system with any object to say nothing about dropping the magnets on the floor or the bench.

In fitting the magnetron block into the oscillator take care not to damage the magnetron leads. Jolts or vibrations can easily disrupt the glass seals with the metal leads.

Particular attention in the assembly and fitting of magnetron oscillators should be paid to the joint of the magnetron output flange with the plumbing leading the microwave energy to the antenna. The joint should provide the transmission of microwave energy without losses and leakage and ensure pressurizing when required.

Magnetron oscillators are fitted to equipment in strict compliance with the drawings, paying special attention to mechanical fastening of all the assemblies and parts of the unit. The soldering points of high-voltage wires should be specially protected. In these points no drops or pointed solder beadings should be left. The shielded wires and coaxial cables should be carefully grounded in the points specified by wiring diagrams.

Tube modulators. Modulators are used for oscillator operation control (switching on and off) in case of pulse operation. The modulator controls the wave-form, duration and repetition rate of the radio-frequency pulses generated by the magnetron. In radars pulse modulation is employed, and the transmitter is modulated by a periodic succession of constant amplitude pulses. The wave-form of the modulating voltage should meet a number of requirements necessary for stable operation of the magnetron in a fundamental mode of oscillations.

Two types of tube modulators are usually employed in radars: employing electron tubes and gas-filled tubes.

In electron tube modulators, during the pauses between pulses, reservoir capacitor *2* is charged from high-voltage rectifier *1* to a voltage required for the modulation of magnetron *5* (Fig. 183). Pulses are formed in submodulator *3* employing one or several electron tubes and generally comprising a blocking-oscillator or multivibrator circuit.

The wave-form and duration of the modulating pulse in this type of modulators are determined by the pulses of the submodulator which makes and breaks the reservoir-capacitor discharge circuit. A partial voltage drop occurs on the internal resistance of discharge tube *4* connected in series with the load, resulting in a comparatively low efficiency of this type of modulators. During the pulse the reservoir-capacitor is not discharged completely and is charged to the required voltage during the pauses

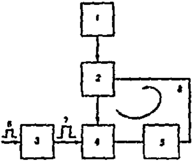


Fig. 183. Block-diagram of a transmitter with an electron tube modulator

1—high-voltage rectifier; *2*—reservoir capacitor, *3*—submodulator, *4*—discharge tube, *5*—magnetron, *6*—synchronizing pulse, *7*—shaping pulse, *8*—direction of reservoir capacitor discharge

In gas-discharge modulators a delay line is charged from the high-voltage rectifier during pauses between pulses The discharge tubes can withstand a high anode voltage and feature low internal resistance and great emission currents

If the power required exceeds the power available from one tube, several tubes connected in parallel are employed. Spurious oscillations which might take place are sometimes dealt with by means of small, of the order of 25 to 50 ohms, antispurious resistors inserted into the anode and grid circuits. In the process of assembly and wiring these resistors should be positioned as close to the tube electrodes as possible making the connecting wires as short as practicable.

Tube modulators are manufactured as separate units Each unit is provided with plug-and-socket connectors which interlink the entire wiring of the apparatus.

Magnetic modulators. These have found wide application in radar. Their principal advantage lies in a practically unlimited service life. The principal function of such modulators is (as in tube modulators) the intermittent connection of a high-voltage and heavy current source to the magnetron. These modulators employ saturation chokes as commutating devices.

ADJUSTMENT

The wide development of radiolocation has resulted in the introduction of a specific adjustment technique which must primarily meet the principal operational requirements of microwave equipment. This is due to the fact that microwave equipment employs capacitances, inductances and resistances that are distributed over the length, surface and volume of microwave elements. Microwave voltages and currents do not have the same sense, as on lower frequency ranges, since their values change along the transmission line and are often impossible to measure.

In the process of adjustment and tuning a radar, the special design features of the equipment should be given due consideration. Radar equipment comprises several diversified devices each of which in its turn is subdivided into units and assemblies. Due to such a design, separate devices, units and subassemblies can be adjusted and tuned, provided the conditions are similar to those under which they operate in the completed equipment.

Adjustment and tuning procedure for principal specific radar devices is discussed in some detail below.

Adjustment and tuning of the antenna and feeder components. The antenna and feeder components of radars (Fig. 184) comprise the antenna itself with inherent components, transmission lines, and the transmitter-receiver high-frequency elements. The waveguide system consists of waveguides with straight *8* and bent *6* sections, rotating joints *4*, cavities *11* and directional couplers *12*.

Electromagnetic energy from the output of magnetron *14* through the antenna TR switch with ATR tubes *15*, waveguide bends *5*; *9*; *10* and adapter *7* is fed to rotating joint *4* which can transmit energy in any antenna bearing position; following that, the energy through flange joint *3* and radia-

tor (exciter) 2 is applied to antenna reflector (mirror) 1. The return path of the reflected signals is the same, though in this case the signals are applied to the receiver input (mixer) 13.

The principal parameters of the waveguide system are: the voltage standing-wave ratio (VSWR); attenuation; dielectric strength; band width generally determined by the permissible VSWR. The quality of the waveguide matching is judged by the VSWR value which is measured on a set-up whose block-diagram is illustrated in Fig. 185. (The drawing represents matching waveguide system 5 with a load.) The measurements are performed with the aid of a special measuring line 3, as well as test oscillator 1 and attenuator 2. The indicating instrument 4 of the measuring line is a microammeter either directly connected into the measuring line detector circuit or after amplification of the detector signal (in case of pulse operation).

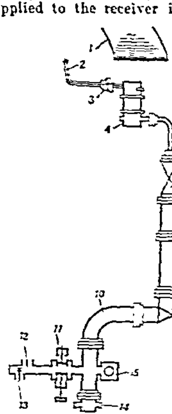


Fig. 184. Waveguide plumbing in a radar antenna and feeder assembly

The voltage standing-wave ratio is determined by the indicator readings in the voltage node and antinode (moving the carriage with the probe along the line) using the formula

$$\mathrm{VSWR} = \sqrt{\frac{\sigma_{max}}{\sigma_{min}}}$$

where σ_{max} and σ_{min} are the indicator reading voltage antinode and node.

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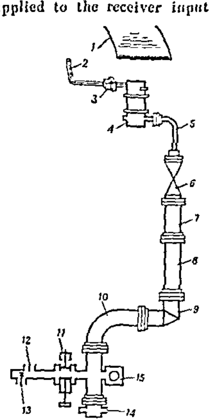


Fig 184 Waveguide plumbing in a radar antenna and feeder assembly

The voltage standing-wave ratio is determined by the indicator readings in the voltage node and antinode (moving the carriage with the probe along the line) using the formula

$$VSWR \approx \sqrt{\frac{\sigma_{max}}{\sigma_{min}}}$$

where σ_{max} and σ_{min} are the indicator readings in the voltage antinode and node

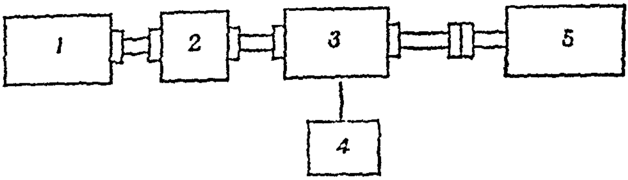


Fig. 185. Block-diagram of waveguide system matching

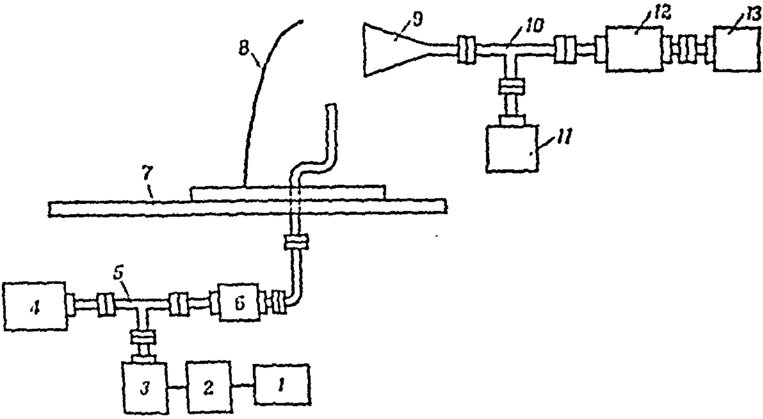


Fig. 186. Block-diagram of antenna pattern recording

The final aim in waveguide system matching is to obtain a voltage standing-wave ratio as close to unity as possible. On achieving the required values of VSWR, the matching elements are fixed in position (e.g. by soldering).

The antenna tuning procedure is aimed at obtaining a given directivity, amplification factor, input resistance and band width. To determine the beam pattern, antenna *8* is placed on rotary table *7* and the instruments are connected as shown in Fig. 186. Antenna *8* under test, together with the measuring attenuator *6*, heterodyne *4*, mixer *3*, amplifier *2* and microammeter *1* make up the installation receiving part. The transmitting part (located at a considerable distance from the receiving part) consists of antenna *9*, fed from heterodyne *13* through attenuator *12*. Heterodyne *4*, mixer *3* and measuring attenuator *6* are connected by means of a T-junction *5* and a second T-junction *10* is used to con-

nect antenna *9*, attenuator *12* and wavemeter with indicator *11*.

The receiving and transmitting antennas are positioned in one polarization plane. Upon tuning the receiving part to the transmitted frequency by the maximum of the milliammeter readings, set the microammeter needle (with the aid of the measuring attenuator) approximately in to mid-scale; these readings are to be maintained constant subsequently. Turning the receiving antenna by a preset angle, set the microammeter reading with the aid of measuring attenuator *6* and record the attenuator reading, thus point by point the beam pattern is determined.

Adjusting and tuning tube-modulator radars. The adjustment and tuning of tube-modulator installations consist of a number of successive steps which can be classified into three principal groups:

preparatory operations, comprising the check-up of the rectifiers which supply the modulator; check-up of the safety-ensuring circuits and the overload relay for insulation;

adjustment of the pulse system (modulator proper), which includes the check-up of the modulator tubes for d.c. operating conditions; check-up of the parameters of the pulses generated by the submodulator; check-up of the pulse repetition rate, inter-unit wiring and the parameters of the modulator output pulse;

adjustment and tuning of the transmitter radio-frequency part which comprise the check-up of the magnetron filament voltage, check-up for presence of radio-frequency oscillations, adjustment of the charging choke inductance value (for gas tube modulators only), measuring the magnetron operating frequency and output power, parameters of magnetron current pulses and the amplitude of modulator pulses, determining the frequencies spectrum of the radiated pulses and inspection of the radio-frequency pulse envelope.

A more detailed discussion of the principal stages of adjustment of radar transmitters with tube modulators is given below.

The modulator is checked for proper assembly and wiring by the wiring diagram, with the tubes removed for the check-up. The check-up procedure for the modulator

rectifiers implies a comparison of their output parameters for compliance to technical specifications. The check-up is carried out on special adjusting test beds provided with active dummy loads equivalent to the actual rectifier loads and with instruments which make it possible to check the magnitudes of all currents and voltages supplied by the rectifiers.

The current overload relay is checked as follows (Fig. 187). Connect the relay winding to a variable voltage source *1*.

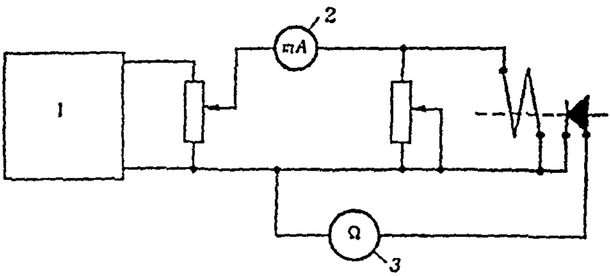


Fig. 187. Circuit for checking overload relay operation

Connect a tester (TT-1 or ABO-5, used as an ohmmeter *3*) to the relay contacts or (when used as a milliammeter *2*) to the relay winding circuit. Gradually elevate the voltage until the relay contacts close. At the instance of contact closing compare the current (read off the milliammeter) with the specification value. The windings of some relays are shunted by a variable resistor thus enabling setting the required relay operation current.

The modulator tubes are checked for the d.c. operating conditions either on a test bed equipped with the required voltages or by fitting into the apparatus and connecting to the regular rectifier. The d.c. operating conditions of the tubes are checked by means of instruments types ABO-5, TT-1 and others. Prior to each measurement the instrument is switched over to the corresponding measurement range.

The successive checking of modulator tubes for operating conditions is also intended to verify that the assembly and wiring have been carried out properly and that the resistances are in compliance with values specified in the diagram.

To check submodulator tubes for dynamic operating conditions apply a starting pulse to the submodulator input from the radar synchronizer. If a master oscillator is provided in the submodulator, it will suffice to simply connect the modulator to corresponding rectifiers. Particular care must be exercised in measuring the parameters of the submodulator output pulses, since these determine the duration and wave-form of the modulating pulse, and hence the duration and wave-form of the transmitter output pulse.

The pulse repetition rate, i.e. the number of pulses periodically generated by the submodulator per time unit, is checked by the Lissajous figures observed on an oscilloscope screen. The oscilloscope horizontal deflection plates are supplied with voltage from an audio frequency oscillator type 3Г-10 or the like; the vertical deflection plates are supplied with the submodulator output pulse. By changing the audio oscillator frequency achieve stable representation of a single pulse on the oscilloscope screen.

A stable image of a single pulse will be obtained on condition that

$$F_{ao} = nF_{pr}$$

where F_{ao} — audio oscillator frequency

F_{pr} — pulse repetition rate

n — an integer.

It is necessary to determine the [illegible] of the audio oscillator on which a single pulse [illegible] obtained. In this position the audio [illegible] read the submodulator pulse repetition rate.

The inter-unit wiring is checked [illegible] purpose instruments prior to connecting [illegible] and its power supply units to the [illegible] inspect the wave-form of pulses applied [illegible] to the magnetron, part of the voltage [illegible] divider should be applied to the [illegible]

The magnetron filament voltage [illegible] filament transformer leads and [illegible] but with the high-voltage [illegible] of the magnetron filament [illegible] dangerous for one's life. [illegible] rule, is automatically [illegible]

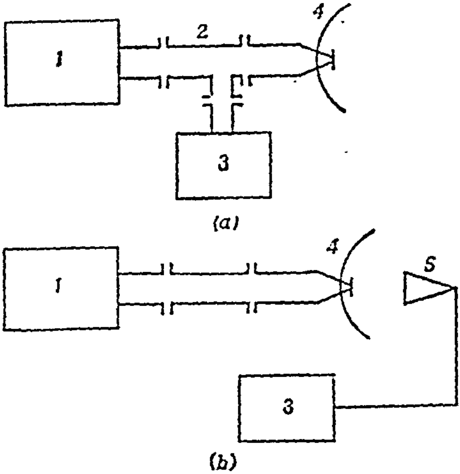


Fig. 188. Block-diagrams for transmitter frequency measurement
a—wavemeter connected by means of a directional coupler; b—space-coupled frequency measurement

voltage is applied to the magnetron. In this case the filament voltage is checked for magnitude or presence by intentionally closing the respective relay or the terminal switch which reduces the magnetron filament voltage.

Prior to fitting a magnetron into a transmitter it should be examined and checked for the degree of magnet magnetization with the aid of a fluxmeter. The magnetron should be carefully centred between the magnet poles, and the magnetron output flange should be joined to the waveguide system. The waveguide output is connected either to the antenna or to an antenna equivalent (dummy load). High voltage, supplied to the modulator, should be slowly increased using an autotransformer. If a new magnetron is fitted in for the first time, it should operate for 5 to 10 min under an anode voltage reduced by half from the normal rating.

Upon application of high voltage make certain that there is no sparking between the high-voltage contacts in the modulator as well as whistles and frying which are indicative of a faulty joint in the waveguide system. Radio-frequency oscillations are detected by an instrument which

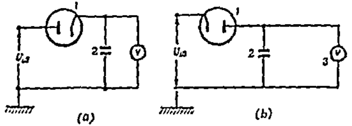


Fig. 189. Circuit diagram of an attachment to static voltmeter for pulse voltage measurements
a—positive pulses; b—negative pulses

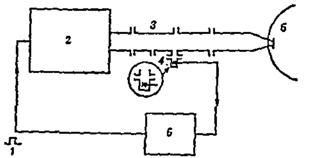


Fig. 190. Block-diagram for h-f pulse envelope inspection

meas ires the magnetron oscillator average current, or by a ra lio-frequency oscillation indicator (if available in the ı.dar set).

The frequency of oscillations generated by the magnetron is generally measured by means of resonance wavemeters. The frequency corresponding to the maximum power in the energy spectrum is the magnetron operating frequency. In measuring this frequency the antenna and feeder components of the radar are used as the load. The wavemeter is connected to the radar either through a special section or a directional coupler. A set-up for measuring the frequency of transmitter *1* with antenna *4* and receiving horn *5* is represented in Fig. 188.

The magnetron operating frequency is measured, after the transmitter thermal conditions have stabilized, adopting the following procedure. With the aid of attenuators position the microammeter needle approximately in the

middle of the scale. Tuning wavemeter *3*, connected via coupler *2*, determine the resonance value of the tuning and take the readings off the wavemeter dials.

The amplitude value of the modulator pulse voltage is measured by means of a pulse voltmeter which, depending on the polarity of pulses measured, is connected accordingly to one of the circuits illustrated in Fig. 189*a* and *b*. Current through kenotron *1* during a pulse charges capacitor *2* to the amplitude value of voltage measured, and static voltmeter *3* measures the amplitude of voltage applied.

The envelope of a r.f. pulse can be inspected on the screen of a slave-sweep oscilloscope (Fig. 190).

Oscilloscope *6* is synchronized from starting pulse *1* of transmitter *2*. Detected radio-frequency pulses are applied to the oscilloscope vertical deflection amplifier. To prevent distortions of the pulse form, the amplifier passband should be wide enough. The crystal detector is inserted into the antenna transmitting line by means of a directional coupler *3* or by means of an attenuator which will ensure attenuation sufficient for the protection of detector *4*.

The r.f. pulse envelope, as well as the magnetron current pulse form are characterized by the duration of the pulse leading front, by the duration of the pulse trailing front, by the magnitude of pulse overshooting and the slope of the pulse top.

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